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DO YOU KNOW . . . .

► . . . . That full information regarding the Lamme and Westinghouse awards and preliminary announcement of two new research honors are contained in this issue? Rules for the YET paper contest were published last month. Now is the time to get plans under way for recommendations and entries. Further details about the research awards—Bendix and Curtis McGraw—and the Technical Institute Division James H. McGraw award will be given in future issues. Nomination forms for awards will be available from your deans after the first of October; blanks will also be available from the appropriate committee members and the Secretary's office.

► . . . . That the Summer Institutes for engineering faculty members at Argonne and Brookhaven National Laboratories were most successful? An evaluation with both staff and students indicates there should be additional programs next year. Present plans of the Atomic Energy Education Committee are for 100 registrants in a general course like the ones offered this year and 100 other faculty members in specialized courses. The former will help those attending prepare to teach a survey course, be adequately informed for intelligent advice to students interested in the atomic energy field, and appreciate the close team-work and interplay of disciplines required to design and build a reactor.

The specialized courses will be designed for those who took this summer's general course and others who by formal training and experience have equivalent backgrounds. Those completing the advanced summer school are expected to be able to teach a specialized course in their own institutions. If this study is then followed by summer employment or by a year's leave in a national laboratory, our colleges of engineering ultimately should be well staffed with engineers suitably trained for nuclear energy instruction.

► . . . . That during the summer your Secretary had the opportunity to visit three of the national laboratories of the Atomic Energy Commission, and that at each one the failure of engineers to avail themselves of summer employment or employment on a leave basis was seriously lamented? Members of other professions have responded, but not the engineers! Why? Some of the laboratories also have plans for summer employment of graduate students and perhaps even of undergraduates. This is in addition to the graduate thesis work regularly conducted.

► . . . . That a list of committees and officers for the current year is on page 172? There will be additions and deletions, but the present status is indicated. You will note that the committees having a specific assignment, with implied discharge on completion of their task, are listed as "*ad hoc.*" During their lifetime their personnel will remain relatively constant; other or "standing" committees usually rotate membership to have some "new blood" brought in each year. That always means that some excellent workers are "retired," and such

action is taken with regret. To those relieved of committee assignments we say, "Many, many thanks for your important efforts and contributions."

The suggestions received last spring for committee appointments were not very numerous. Consequently each committee chairman specifically was informed at the time of his appointment that making recommendations at the end of the year was part of his job. All Section and Division Chairmen and members of the General Council also are asked for suggestions each year.

► . . . . That since the '56 Yearbook was submitted for printing, 28 new associate institutional members have been added to the Society's membership? During the same period of time there have been four resignations, three of them steel companies. Each of you who have contacts with representatives from industry, particularly recruiters, should inform them about this valuable type of Society membership. The Associate Institutional Membership Committee will be pleased to have your suggestions, and the Secretary's office will gladly forward information if you provide the names of interested companies and especially those of appropriate personnel or executives.

► . . . . That the YET Committee again wants to conduct the individual ASEE membership drive for the Society this year? Last year's efforts were successful at some institutions, but at many there were no efforts at all. This year it is hoped each institution will have an active campaign. Every Section representative on the YET Committee will be responsible for getting a YET on each campus to head the drive. The Secretary's office will then write each dean, informing him of the representative and requesting that the two develop an effective program. The necessary supplies can be obtained through the YET Committee or directly from the Secretary's office. But each member alone has a responsibility in promoting membership—so, tear out the application blank on page 192 of this issue and give it to a colleague, NOW!

W. Leighton Collins
Secretary

OAK RIDGE RESEARCH PARTICIPATION PROGRAM

College and university faculty members may now apply for places in the 1957 Research Participation Program, designed to aid educational institutions by helping faculty members spend summers or other periods in research at Oak Ridge, with university-equivalent salaries. Information and application blanks, for return by December 15, 1956, can be obtained from the University Relations Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee.

RESEARCH NEEDS OF ENGINEERING AND THE ENGINEERING SCIENCES AND HOW THE NEEDS SHALL BE MET

HAROLD K. WORK

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Presented at the first General Session of the Annual Meeting, June 25, 1956.

During recent years there has been considerable confusion about engineering college research. Such questions have been raised as 1) What should it be like, 2) How much should there be, and 3) Who should support it? These brief remarks will present what the Engineering College Research Council of the ASEE and the National Science Foundation are doing about the above problems.

It is most appropriate to start this discussion on engineering research by referring to the research policy adopted by the ECRC two years ago. The policy summary is as follows:

". . . the research program of an engineering school should properly embrace the following types of activities:

a. Research to discover scientific principles and facts which will advance the science of engineering.
b. Applied research or development of specific devices or processes which will develop the competence of teacher and student, thereby serving the engineer in a manner parallel to the clinical studies of the physician.
c. Activities which serve the public interest, as for national defense, public health, or general industrial and agricultural progress."

The first item includes what engineers generally think of as basic or fundamental engineering research. In general, this type of research is not too well understood or too well supported. Yet it is most generally accepted as a highly desirable type of activity for an engineering school. It fits in with the concept that a university should develop new information as well as disseminate the old.

The second item—applied research—is currently being adequately supported financially but not everyone welcomes it to the university. The fact that it is included in the policy is predicated on the feeling of engineering educators that applied research constitutes an important part of the training of engineers. Far more engineers go into applied research and development than into basic research. The current support comes largely from industry and the Department of Defense, and appears to be adequate.

The third items includes those services that a university performs for the community. Such activities seem to have a regional character. For exam-

ple, in areas where no one else is available to do this work, the schools will do routine testing. Where this kind of activity is needed, funds seem to be available from local sources.

From the above, it can be seen that the basic research, or whatever you care to call it, presents the most serious research problem of the engineering colleges. Part of the trouble stems from the difficulty in defining such research. The word "basic" has a dictionary definition of "foundational or underlying" and a search for foundational or underlying information would seem adequately to describe basic research. However, because some successful basic research has resulted from work which was not directed at any objective but the securing of information, there has been a tendency on the part of many to feel that all basic research must be handled in similarly unmotivated fashion. If this is accepted, then basic engineering research faces a dilemma. It is hard to conceive of much engineering research that does not have a more or less clear objective. This follows from the definition of engineering which is sometimes described as follows:

"Engineering is the art and science by which the properties of matter and energy are made useful to man in structures, machines, and products."

Working under such a definition of engineering, it is difficult to conceive of much engineering research that is not directed to some useful purpose. Hence, if the work must be without the above goal, it can hardly be engineering; rather it must be in the basic sciences. In view of this, it seems appropriate at this point to take a fresh look at the definition for basic research in engineering. If the definition is predicated on what is sought rather than how it is sought, it is believed that much of the above confusion would be resolved.

Now the question of the need for such research will be briefly considered. Just whose need is involved? It can hardly be called a need of the engineering colleges. Insofar as their operations are concerned, they can operate as just academic institutions. Many do substantially that now. The need unquestionably refers to the needs of the country as a whole. There is a certain amount of basic research required to serve as a foundation for efforts to improve public welfare for technological advancement and for national defense. Of this basic research, there is a certain part that the engineering colleges of the country can best handle. That it has not been as effectively supported in the past as it should have been has unquestionably resulted from a lack of clear understanding as to who should support it.

The problem of satisfying this need has been of concern both to the National Science Foundation and the Engineering College Research Council. During the past year, this subject has been discussed by these two groups and the discussions finally culminated last week in the granting by the National Science Foundation to the ASEE a sum of $40,000 for the study of research needs in engineering. The study will be under the direction of Eric A. Walker, President of The Pennsylvania State University.

To avoid controversy over definitions, the research will be merely characterized as research which engineers do. The survey will be limited to the

staffs of colleges which have accredited curricula in engineering. Only the *present* capacity to do research will be considered. This will include what is now being done, or could be done without any substantial increase in staff. The estimates will be further limited to an amount that the college administration feels can be handled without curtailing teaching capacity.

It is tentatively planned to carry out the above study with a staff consisting of a project director, a technical assistant, a secretary, and a team of investigators. Steps toward setting up a questionnaire and procedure for obtaining uniform results will be taken shortly. An attempt will be made, as far as possible, to include facility requirements, as well as those for personnel, in addition to an analysis of the data collected.

This report should help considerably in delineating the needs of the country in engineering college research. Once these needs are clearly defined, methods should readily be found to take care of such activities. The ECRC, in particular, and the ASEE, in general, are both deeply grateful to the National Science Foundation for making this study possible.

SECURITY POLICY ON UNCLASSIFIED RESEARCH

The American Council on Education recommended in December, 1954, that "Educational institutions should not permit any outside agency to determine the fitness of any staff member for working on unclassified projects. The government should not impose restrictions on the selection of institutional personnel for unclassified research supported in whole or in part by government grants. Current tendencies to require special clearances or security tests for such personnel are inimical to the progress of learning and improper in terms of the handicaps placed upon investigators and their institutions."

Under the chairmanship of Dr. J. A. Stratton, Vice President and Provost of M. I. T., a special committee of the National Academy of Sciences, which was appointed early in 1955 at the request of the White House, submitted a report expressing agreement with these ideas. On August 15, 1956, Sherman Adams, Assistant to the President, sent a letter to Dr. D. W. Bronk, President of the Academy, stating that these principles would be the basis for future actions regarding federal grants or contracts for unclassified scientific research.

Presenting

GENERAL EDUCATION IN ENGINEERING

Report of the Humanistic-Social Project

EDWIN S. BURDELL

Chairman of the Committee
and President, The Cooper Union, New York City

Remarks at the General Session on June 25, 1956.

Dr. Gullette and I are happy to present to you this morning "General Education in Engineering" as a report of the Committee of the Humanistic-Social Project which was accepted by Council last evening. On May 11, I sent eight copies to each dean of engineering with the request that he send them to those members of the liberal arts faculties who would not be likely to see them otherwise. I assume that most of you in this audience have had access to the report, but considering the time of year of its appearance, you may not have had occasion to read it very carefully. We want to have as wide a distribution, examination, and comment as possible, especially among the vast majority of your colleagues on your campus who are not members of ASEE. Dr. Gullette will tell you, among other things, the procedures by which additional copies may be secured.

My purpose this morning is to say a few words about the findings of the Humanistic-Social Research Project and its place in the stream of literature on the field of engineering education. In one sense our investigation is a by-product of the work done by the Committee on Evaluation of Engineering Education, which made its final report to the Society at the last annual meeting. In another sense it is a continuation of the work of the 1944 Committee on Engineering Education After the War, which reaffirmed the recommendations of the 1940 Committee on the Aims and Scope of Engineering Education. In my letter of transmittal to the deans of engineering, I pointed out that the Committee on the Project adopted the principles and objectives of engineering education as set out in those earlier significant reports. We could find no fault with these basic objectives ten years after their promulgation.

We therefore proceeded on the assumption that the engineer is not adequately prepared to make an effective contribution in today's world if he has not acquired during his undergraduate study some sense of human values and some knowledge of the social, economic, and political world in which he will play a conspicuous part. We wanted to find out if professional competence had to be sacrificed in order to give an undergraduate an understanding of himself and of the world about him. We sought to find ways to provide both technical skills and human values, because we hold that professional competence may be seriously jeopardized if the student has not acquired knowledge and skills beyond those required by the engineering sciences and technology.

We believe that the engineering schools have the responsibility to develop in the undergraduate a capacity for both intellectual and emotional growth in directions which we ourselves can today but dimly visualize. We would observe that capacity and desire to grow in knowledge and wisdom are a test of the success of the total educational endeavor, especially of the humanistic-social studies. We know full well that with only one fifth of the time devoted to this field, all that even the most effective teaching can do is to open doors and windows to future study.

We have stated in the Summary of our report that although there is nearly unanimous agreement among engineering educators that the humanities and social sciences have a place in the curriculum, a sizable number of them are fearful that attempts to develop them in the already overcrowded courses will jeopardize the quality of the technical education and at best provide only a superficial treatment of the nontechnical subjects. To these educators particularly we have addressed ourselves because we have located in our survey thirty or more of our leading engineering schools which have demonstrated such fears to be groundless by regrouping their science and technology courses and by placing on the graduate schools and on industry the responsibility for specialized instruction. We have confined our report chiefly to the practical problems that confront those who must plan, initiate, and maintain humanistic-social programs for engineering students.

Perhaps our most fundamental recommendation is that there cannot be and should not be a ready-made program for all schools. No standardized pattern is available for teaching the humanistic-social studies any more than there is for teaching mathematics, science, or technology. Each school must hammer out for itself a feasible program in terms of its own local resources of staff, library, and audio-visual aids inside the college or university, and access to music, art, and drama outside in the community.

Certain valid general observations, however, can be made and for the sake of brevity can be summarized as follows:

Humanistic-social programs for engineering students are successful when these conditions prevail: There must be a vigorous administrative support for the program. No half-hearted effort on the part of a dean or department head will be able to cope with the indifference or hostility of some die-hards on his science and engineering faculty, nor be able to marshal the teaching personnel necessary to present humanistic-social subject matter from a vigorous, fresh, and experimental point of view. No hackneyed sequences of courses will challenge the interest of the student or take advantage of the high caliber of the entering student and of his increasing intellectual maturity and curiosity as he completes his upperclass years.

The faculty and the administration must conceive of the humanistic-social studies as an integral part of the student's total educational experience semester by semester, and not as a "pre-heat treatment" intensively applied perhaps more conveniently in some preliminary college experience or as a sporadic sort of sheep dip that is administered intermittently through the eight semesters when and where there happens to be a gap in the heavy

concentrations of mathematics, engineering sciences, and technology.

The principal educational problem external to the school of engineering itself is that of establishing full cooperation and understanding between the engineering and liberal arts faculties. We found a strange contradiction between some engineering colleges located within universities where liberal arts resources were unusually rich but courses in the humanistic-social studies were poor, and on the other hand, some independent engineering schools where such resources were meager but integration and good teaching did exist.

Perhaps this is the central problem so far as the engineering dean on a university campus is concerned. He must see to it that the representatives of his faculty *do* collaborate successfully with representatives of the other faculties. Of course in the last analysis, the president of the institution is responsible for assuring effective coordination.

As an example of the lack of coordination between engineering schools and their sister colleges of the arts, I came across in one of my field visits a situation which I described as follows on page 54 of our report:

"My impression of the relationship between the School of Engineering at X University and the Liberal Arts Division was that there was much good will but not much intelligence applied to solving the problem of establishing an integration of the humanistic-social stem with the scientific-technological stem. I received the distinct impression that the engineering faculty prescribes so many credits of humanistic-social studies and the liberal arts faculty fills these requirements as a pharmacist fills a prescription. The doctor doesn't consult the pharmacist or vice-versa and the patient hasn't the faintest notion of what the medication is or why he is taking it. Stranger still, the doctor doesn't examine the patient or rewrite the prescription either in terms of need or of new pharmaceuticals."

In conclusion I might refer to a Boston journalist who, in commenting on the report soon after its publication, said: "The Survey found that, while many engineering schools give lip service to the principle of broad education, their practice of it can be greatly improved. There still is a point to the jibe that liberal arts colleges are trying to humanize the sciences, while the engineering schools are trying to Simonize the humanities."

Well, I hope that the Report of our Humanistic-Social Research Project will help to reduce that jibe to nothing more than a bad joke. I hope that none of our engineering schools will take the humanities to be merely a sort of Simonizing job to make the students *look* shiny. Eventually I hope all engineering schools will consider the humanities and social sciences as an integral and essential part of professional education.

MANAGEMENT SCIENCE AND OPERATIONS RESEARCH

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Presented at the ECRC General Session of the Annual Meeting, June 27, 1956.

New science and new mathematics always yield an increased potential for engineering. Any such advance, whether in experimental physics or in the theory of differential equations, may well lead to solutions both of old and new engineering problems. Similarly, a new engineering problem may pose a mathematical or scientific question that either is easily answered on the basis of existing knowledge or else leads to further fundamental research.

Management science and operations research are new names for old kinds of science and engineering. These newly named fields identify a rapidly growing effort to solve many old types of problems through the application of engineering art and scientific method. This effort is producing new mathematical structures and scientific knowledge, first stored in professional journals and then applied over and over again as a developing engineering art.

An example is the mathematical structure consisting of a system of linear algebraic equations in non-negative variables. This relatively unsophisticated mathematical structure is adequate to represent the class of practical problems treated under two theories currently popular and important in management science and operations research, namely: linear programming theory, and two-person constant-sum matrix game theory. Closely related to these is statistical decision theory, in which fundamental concepts and theorems from the mathematical theory of probability combine with others from game theory to provide a powerful analytical tool for use in operations research.

The establishment of an operationally meaningful correspondence between the abstract entities of systems of linear equations in non-negative variables and each of several types of familiar management problems constitutes an addition to management science—scientific knowledge that can and will be put to good use over the years by engineers concerned with design, construction, operation, and control of systems and processes.

What do these developments in management science and operations research mean for those of us who are concerned with the proper education of engineers? What are the special implications for the pre-engineering, bachelor's, master's, and doctor's programs? What are the implications for the established engineering specialties? What new engineering fields are emerging?

Rather than try to answer these questions explicitly in terms of curriculum, we shall answer indirectly by indicating the broad outlines of scientific knowledge and engineering

skills that seem to be most useful now to practitioners of operations research –whom we shall here call "operational engineers." We shall also venture a guess as to future trends.

Operational Engineering

One essential skill of the successful operational engineer is the ability to simulate the system or process, with which he is concerned, by a model that he can first test for validity and then manipulate to determine expected system behavior under alternative conditions of interest. The model is apt to be at least partly mathematical in form, and the manipulations are apt to make substantial use of some body of mathematical theory. He has this skill in common with most other engineers, with the difference that system and process models seem to range over a very much wider domain of mathematical disciplines than do models from more familiar engineering fields–where, for example, some system of differential equations often suffices. Success in modeling complex systems and processes depends more often upon a very broad knowledge of mathematical disciplines than does such success in more conventional engineering practice, at least at present.

Another essential skill of the successful operational engineer, and one that is desirable in all engineers, is the ability to design, conduct and analyze an efficient experiment adequate to test the validity of a system or process model. Until more powerful general theories are available for the treatment of complex system and process engineering problems, it will often be necessary for the operational engineer to use the most powerful techniques available from the fields of experimental and mathematical statistics in the course of his experimental work–a sophistication of the trial and error process.

Complex systems and processes of interest to the operational engineer invariably include human beings, either as direct participants or as responsible managers, and a difficult but critical requirement for adequate modeling and experimentation is proper treatment of these human factors. Indeed, the human factor must be of essential importance in the problem or else it falls outside the usual domain of interest to the operational engineer. For this reason, the operational engineer needs a much broader background of knowledge from economics and the other behavioral sciences than does the man who is dealing with more conventional engineering problems where human factors are not so critical.

It is not often possible, at the present time, to bring a complex system or process into the laboratory for study. Consequently, the operational engineer very often finds he is affecting the behavior of the system while he studies it. Furthermore, his success may depend more upon his ability to obtain and retain the confidence and goodwill of individuals within the organization he is analyzing than it does upon scientific knowledge and technical skill. He is helped greatly in this if he has a good understanding and appreciation of the motivations and skills of the managers and operators, and of the technological characteristics of the physical components of the system or process. Thus, scientific and engineering knowledge alone is not enough; legal, financial, and political restrictions are often as decisive in a model as are the ones

derived from technological considerations—so are ordinary inertia and natural human resistance to change.

Warehousing Example

As an example, consider a typical problem of warehouse location and design. The transportation version of linear programming theory might be used to determine an optimum pattern of shipping schedules from plants to warehouses, in terms of calculated customer demand and plant outputs. Statistical inventory control theory might be used to determine an optimum pattern for production and stock levels, taking account of expected uncertainties in customer demand and in prices. Optimum operating conditions determined in this way for each of several alternative warehousing schemes would provide a basis for an overall economic comparison of the several schemes, in rather typical operations research fashion. An analysis of this kind, done in the best modern manner, would make use of quite advanced mathematical theory and would tax the capabilities of the best of our electronic computers. Yet the conclusions of the analysis would be greatly affected by assumptions such as:

The discount rate used to measure rates of return from capital investment schedules,

The amount assigned to measure the loss due to inability to fill a customer's order,

The growth rates of own and competitive markets.

Nevertheless, the operational engineer is often able to analyze the expected behavior of the overall system, for each of a variety of such assumptions, and to do so well enough to give the responsible manager a much sounder basis for decision than would exist without the analysis.

Electronic Computers for Simulation

Our warehousing example illustrates another characteristic commonly found in management science and operations research, namely the use of high-speed computers to simulate the behavior of complex systems under alternative assumptions. Computer simulation often makes possible rapid manipulation of mathematical models, that are too complicated to handle algebraically, as an aid in management science. Computer simulation also often makes it possible to introduce human judgments directly into the analysis, in a systematic manner, and thus to give proper attention to many human factors that are otherwise unmanageable. Clearly, the operational engineer must be skilled enough at the computational art to make full use of this powerful tool.

Human Engineering

Some operational engineering problems relate to systems or processes in which the non-human element is quite unimportant. As one example, current work on information handling and decision-making in small groups is producing a wealth of mathematical theory and experimental findings that constitute new management science ripe for operational engineering applications. Some of these results have apparently led to improvements in design and operation of certain military information-handling systems, in which the physical components are entirely secondary, and it is logical to expect that many similar applications will eventually be made to non-

military systems. Among the many mathematical topics encountered in recent scientific literature on small group behavior are: stochastic processes, information theory, matrix theory, linear graph theory, servomechanism theory, and game theory. These mathematical topics are now as unfamiliar to most engineers as is the scientific literature in experimental social psychology, but it seems likely that increasing use will be made of this type of knowledge by some engineers in the future.

Considerable use is already being made of experimental results from the fields of physiological-psychology and anthropology. This work is usually called human engineering, and most frequently is concerned with the design of equipment so that it can be operated or occupied by a person or team in an effective and comfortable manner. Familiar examples are design of airplane cockpits, tank turrets, automobile interiors, submarine interiors, radar consoles, gun turrets, process control instruments, and the like. Human engineers have made very little use of advanced mathematics in their work so far, although servomechanism theory is now getting some use, but they have made extensive use of the wealth of experimental results available especially from the fine work in psycho-physics over many years past. Only recently has American industry begun to take a serious and active interest in human engineering.

Automation

Automation is a development that deserves mention here, and one that will be greatly affected by operational engineering advances in the future. The automatic loom, the automatic telephone, the automatic pilot, the automatic antiaircraft battery, the automatic machine tool, the automatic refinery, the automatic office, the automatic factory, and the automatic company are all systems controlled ultimately by human beings but more and more completely mechanized in their internal operation. Before mechanization of each of these systems is possible, it is first necessary to understand the information-handling and decision-making roles of the former human operators and then to devise machines to perform these functions.

Automation is technical evolution, not revolution, and will be aided by most branches of science and engineering. Perhaps the most challenging automation problems at present are those pertaining to control during operation. In the completely automatic refinery, a master computer would continuously receive and process data that would not only establish internal process control but that would also determine production schedules, yielding product outputs in an optimum manner in terms of market demand and prices. It is rumored that one company in the petroleum industry is already well along with the construction of just such an automatic refinery.

Office automation is now an especially attractive area for operational engineering. Mechanized inventory control systems must be based on carefully chosen principles for determining optimum inventory levels and reorder rules, since as the system is more fully mechanized it becomes increasingly difficult to recognize and correct errors—the inevitable price one pays for substituting an inflexible machine in place of a flexible human. Considerable knowledge of mathematical inventory control theory, and of

computer capabilities, is now needed by an engineer responsible for the installation and operation of an automatic inventory control system.

Mere mention of the vast effort now concentrated on weapons systems evaluation and military operations research should be adequate to call attention to the increasing need for operational engineers within our defense effort. Unfortunately, security restrictions on this work often keep these new advances out of our educational program too long. However, it is imperative that our overall program of engineering education take full account of these developments in so far as they indicate desirable changes in curriculum. It is already evident that a great deal more emphasis should be placed on fundamental subjects, such as modern mathematics and the behavioral sciences, if our engineers are to be prepared to cope with the kind of systems and management problems encountered in office and plant automation.

Professional Developments

Two new professional organizations and journals have been founded in the United States since the Korean War, in the management science and operations research area. Several similar societies have been organized in other countries, and others are being started.

The Institute of Management Sciences and the Operations Research Society of America each have over a thousand members. *Management Science* is the quarterly journal of the Institute and *Operations Research* is the bi-monthly journal of the Society.

Several of these organizations are cooperatively sponsoring an international conference on operations research and management science, that will probably be held in England during 1957.

There are also a number of other new organizations and publications concerned with one or another aspect of the general area under discussion here. Important among these are the Society for Industrial and Applied Mathematics and the Association for Computing Machinery.

Some attempt has been made by the Operations Research Society of America to establish professional standards for operational engineers. This Society has three grades of membership, with requirements on education and experience somewhat like those familiar within the older engineering societies. However, there has as yet been no real attempt to create a separate engineering profession and it seems unlikely that this will happen in the near future. In fact, it is difficult to see how professionalization either can or should precede the establishment of a strong educational program.

Educational Developments

Several American universities now grant advanced degrees in fields with names that are variants of management science or operations research. These new programs are usually started and administered by an existing department, or by a special Committee, and the curricula and degree requirements vary widely from school to school. The Education Committee of the Operations Research Society of America has been studying this problem, and has sponsored two well attended conferences at which representatives from colleges having such programs met to exchange views and to find points of agreement.

At Columbia University, for example, a student interested in management science and operations research may earn either the Doctor of Engineering Science (D.Eng.Sc.) degree, or the Doctor of Philosophy (Ph.D.). Candidates for either degree work under the direction of members of the faculty of the Department of Industrial and Management Engineering, and elect "Operations and System Engineering" as their field of specialization. Each student must have a Master's degree before he is admitted for doctoral study, and either his Bachelor's or Master's degree must have been taken in some field of physical science, behavioral science, engineering, or mathematics if he is to meet the requirements for admission. His course work and doctoral research may be in any areas that relate to his approved dissertation topic, and his problem can be anything that is worthy of scientific research if it pertains to management or systems engineering. Dissertations recently accepted have treated problems such as:

A quantitative methodology for decision-making in plant layout,

Optimum criteria in telecommunication system planning,

Operational aspects of the accident proneness concept.

These dissertations have made good use of mathematics and mathematical statistics beyond that taught in the regular college engineering course, but not beyond that covered in a good Master's degree program in mathematical statistics. Specialized technological information was needed and used in each case, and in the three quite different areas in which the men had considerable professional engineering experience. Some use was made of information theory, and of a mathematical theory of clique formation, in the dissertation on telecommunication system planning.

An analysis of the papers being published in the professional journals of management science and operations research, and of doctoral dissertations in this general area, indicates that minimum levels of maturity required for successful work in this field are roughly as follows:

For original research—the equivalent, through education or experience, of: a Master's degree in mathematical statistics, a Master's degree in some experimental natural science, a Doctor's degree in the field of application, and a flair for model construction.

For professional engineering practice—the equivalent of a Bachelor's degree in mathematical statistics, a Bachelor's degree in some experimental natural science, a Master's degree in the field of application, a thorough knowledge of one or more special techniques of operational analysis, a general knowledge of electronic computers and their capabilities, and a flair for working with others either as a consultant or as an interdisciplinary team-member.

For the graduate operational engineer—the equivalent of a standard pre-engineering program except for the substitution of introductory courses on mathematical statistics, scientific research, and electronic computers for the usual courses on graphics, mechanics, and second year chemistry; a two year engineering program to include most of the courses now common to all engineering curricula, and the balance especially designed to cover the fundamental techniques and uses of operational engineering.

The Future

At the present accelerated rate of production of papers and books on various aspects of management science and operations research, it seems reasonable to expect that there will be full-fledged graduate degree programs in operational engineering in a number of schools by 1960. These programs will probably continue to be called by a number of different names, and be otherwise organized and administered in a wide variety of ways, for several years after 1960.

Introduction of special operational engineering courses in the undergraduate program is already started, and there should be quite an increase in the number of these as soon as a few more of the authors now completing usable texts finish their work. It is reasonable to expect that many of the highly specialized topics that now receive so much attention in our training programs, such as the simplex method and other computational algorithms for special problems, will gradually be replaced in our educational program by material of more fundamental importance for the field as a whole.

As experience with a number of similar cases shows particular models to have effective and important applications, these models and the techniques for their engineering use will undoubtedly become the subject matter of special courses. Both the mathematical programming model and the statistical inventory control model are already well along toward this stage. Indeed, at the pace things are now moving, within a decade we may even have specialties within operational engineering for some of these.

In Conclusion

Operational engineers need a good working knowledge of modern mathematics and statistics, their approach to problems is much the same as that of the research scientist, they must cope with the economic and human aspects of complex systems problems, and the electronic computer replaces the slide rule for their work.

Progress in management science and operations research is already adequate to provide the basis for a worthwhile educational program. The rate of progress is so great that operational engineering could easily emerge as a new branch of the engineering profession within a few more years. It is a worthy challenge to engineering education to develop an adequate and timely program to meet these evident professional needs.

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1957 June 17–21 Cornell University, Ithaca, N. Y.

1958 June 16–20 University of California, Berkeley

1959 Carnegie Institute of Technology, University of Pittsburgh, Pittsburgh, Pennsylvania

1960 Purdue University, Lafayette, Indiana

THE IMPACT OF MODERN PHYSICS ON ENGINEERING EDUCATION

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Research in Modern Physics has had for engineering a double impact; on the one hand dramatic and public, yet apparently remote, and on the other diffuse and specialized, a process of infiltration from pure science. In engineering neither salient has quite been recognized for what it was.

When the atomic bomb fell on Hiroshima, the shock wave it produced was more than physical. Here was a completed technical accomplishment, in limited production under profound secrecy restrictions—a new source of power, whether destructive or constructive, a new major factor sprung full-blown from science to influence the political life of the world. Recognition came quickly that new methods and new wisdom were needed in political and social thinking, in the approaches to war and peace, to force and compromise, to international trade and cooperation.

Naturally but unfortunately, wisdom to cope with these new situations does not come as quickly or easily as the admission of need. What is more troublesome, in our general preoccupation with political and international consequences, engineering educators have been slow to face the profound revisions this contribution of the physicists requires in our thinking about energy sources and power conversion, about materials and structures and their uses.

While the political shock of Hiroshima was obviously a direct result of research in Modern Physics, other advances had been achieved more gradually but with equal significance for engineering progress. These, however, were not signalled by a single earth-shaking breakthrough——neither in pillar of mushroom-cloud by day, nor in pillar of fire by night. Even more readily than with nuclear fission, therefore, the inclination of engineering was to consider such quiet developments as belonging to "pure" physics research. Alternately, engineering tended to accept the help offered in tools or products (such as electron microscopes, fluorescent tubes, or transistors and semi-conductors as vacuum-tube substitutes and supplements) without attempting to understand fully or study deeply the new principles and knowledge which had made such conveniences possible.

An External View

Thus engineering has been tempted to stand aside from both these areas —the dramatic and the silent frontiers alike—to view them externally, as outside, not really as part of engineering. Being engineers, we remain interested in the macroscopic world of relatively large objects, especially so because the synthesis of new devices or services to meet man's needs inherently

requires materials in aggregates of observable size.

We have been impressed with the complexity of these new realms, the uncertainty which requires statistical predictions of group or range performance where we had previously counted on mathematical exactitude. We have been deterred by the realization that the observations in this new physics are no longer direct and visual, but oblique, secondary, and inferential. This has been a problem even for electrical engineers who have always worked with indirect measurements. In this sub-microscopic world of the nucleus, the best information comes from far more indirect effects than we are accustomed to, from indications at second or third hand. It is all too easy to leave these principles and results for those who already understand them, and to continue our dependence upon the Newtonian and post-Newtonian concepts, including the absolutism of matter and energy.

Engineers have long been accustomed to warn of the dangers inherent in extrapolation, either through time or space, beyond the range of reliable and immediate observation. If extrapolation is unavoidable, one pays attention not only to the magnitudes of quantities in the observable range but also to the rate at which these quantities are changing (first derivative), to the rate at which the rate is changing (second derivative) and so forth. In the realms of Modern Physics, as with ideas of human conduct, it is more difficult to do this because its language is a language of probabilities. The application of judgment is then inevitable, and it is all too convenient for us to define these areas as being "outside engineering" . . . to be left to those interested in Modern Physics—or in modern politics, for that matter.

A Definition

With this background, perhaps before we proceed too far we should define "Modern Physics," as contrasted with "Classical Physics," at least for the purpose of our present discussion. We can not define it as "the Physics in which a modern physicist is interested," because there are still many areas of classical physics which would fall into that category, even though some engineers might question this. Also, many of the problems of classical physics which are of interest to and are being attacked by both physicists and engineers are yielding primarily not to new physics but to new tools of mathematics such as nonlinear differential equations and electronic computers.

A more meaningful definition for our use, and one which would be generally accepted by physicists themselves, is that "*Modern Physics is the study of atomic, nuclear, and solid-state phenomena, and the understanding of these through quantum theory.*" One most important result of activity in areas so defined, for which the effects of extremely high velocities or extremely small particles assume importance (requiring the application of relativity and statistical mechanics or other new principles to avoid errors), has been the recognition that physical laws are no longer absolutes.

Even after Einstein's promulgation of the relativity principle and the equation $E = mc^2$, Newton's laws and those involving the conservation of matter and energy were still accepted quite generally as being adequate for our earth-bound physical situations.

The practical transformation of matter into energy seemed a fantastic dream, possible only in the sun and more distant stars. Relativity and its consequences appeared to have their principal applications in the deflection of the sun's rays during an eclipse, or in the orbital perturbations of Mercury. Hence many engineers were "educated" and graduated between 1905 and 1940 without knowing of the existence, certainly without appreciating the implications, of the revolutionary equation relating mass and energy. For somewhat the same reasons, more recent graduates were in danger of remaining ignorant of the scientific developments in physics research from the 1920's onward. And then came the atomic bomb!

Another essential innovation has been the recognition that the operations of physical laws are statistical in nature, rather than exact, fixed relations between cause and effect. One can no longer hope to predict what *one electron* will do in a particular environment; one must, instead, plot on a probability basis the expected behavior of electron groups or populations as they react to electric or magnetic fields. By Heisenberg's Uncertainty Principle, we do not know exactly where an electron is or where it is going any too well. As a matter of fact, this principle is very closely related to some of the fundamentals of communication theory.

Under these conditions, Ohm's law becomes a statistical statement applying to large assemblies of electrons in much the same way that actuarial data are used to compute insurance rates. Under the light of modern physics research, indeed, electrons have come to seem much more like people—unpredictable as individuals, but safely predictable en masse. Physics and sociology do not seem as far apart as they once did.

Quantum theory, the most important of our criteria for Modern Physics, was difficult even for physicists to accept, perhaps because of its compromise function role as a bridge between wave and corpuscular concepts, and partly because it has never been completely satisfactory even in this conciliatory position. It has, however, had valuable implications, chief among them the clear indication that the world of the atom, the electron and nucleus, the proton and neutron and "hole" can not be described by models, but only by new equations, new concepts of *discrete* rather than continuous phenomena. This has posed a troublesome barrier to the engineer, whose professional task of synthesizing devices and services to meet man's needs has always utilized physical interpretations or models, plus insight and guided intuition.

For many years, the research attention of physics, by contrast, has been in these directions of sub-atomic, indirectly studied, reflected behavior operated upon by inferential methods. The advances from these studies have seemed both vague and far removed from the concrete realm of the engineer. Thus a gap developed between the new frontiers of physics and the everyday work of engineering production or instruction. This gap continued to widen, and in a sense has been recognized in bulk and substance by the requests of college physics teachers (as formalized in the American Institute of Physics Report) for what amounts essentially to a second course in physics, superimposed on the traditional classical approach to engineering fundamentals.

What this request says, in essence, is that the accumulated knowledge in the new atomic and nuclear realms is approximately equivalent to that ordinarily covered under the classical or traditional headings, and that physicists think these fresh areas of knowledge should be added to the equipment of all graduates in engineering.

How Approach?

Various approaches have been tried to avoid overburdening the curriculum. In any case, the response of engineers must not be merely passive or neglectful of the new knowledge and principles brought us by physics research. Any thoughtful consideration of the work actually done and the results available will convince us that we should not return to the generally complacent attitude characteristic of physics in the late nineteenth century and of engineering in the early twentieth. There is today no justification for any confidence that engineering design can continue to be based almost entirely on classical physics, that traditional ways of thought will long be adequate for professional use in engineering, that devices perfected by physicists can be successfully adopted *in toto*, or that Modern Physics itself is "the study of those problems you meet only if you study Modern Physics."

Effects on Engineering

Major developments should shatter this complacency. On the dramatic side, unlike most young things, atomic energy was born and first applied with an initial size at the upper end of the dimensional spectrum (as might well have been anticipated from the c^2 in Einstein's equation). This means that as a power source, a danger, a modifier of materials, both fission and thermo-nuclear phenomena threaten directly our past assumptions and practices about structures and machines. Engineering products must not only be designed to resist greater shock, but attention must be paid to contamination and to radiation exposure resulting in changes of physical properties such as elasticity and heat conductivity. Even crystal structure is altered under neutron bombardment.

Before specifying his reactor building or his heat exchanger, therefore, the civil or chemical or mechanical engineer must consider whether in the presence of radiation and its products the materials he has been accustomed to use can be counted on as having the properties he has been in the habit of assuming for them. His steel may no longer effectively be steel, and some esoteric new alloys or elements may be demanded, with unique processing requirements, to give the qualities which in the past have been attained more easily.

Furthermore, as contamination is a function of the materials exposed, and the nature of the radiation, structural engineers must have an understanding of isotope production and of the half-lives involved for different elements. Prediction is more difficult. In addition to the traditional characteristics related to strength, weight, and ductility, new constants must now be understood and evaluated for many materials. Similarly, design of structures and devices to resist radiation as well as shock requires scarcely less unrestrained and radical imagination than the safe but economical and permanent disposal of atomic waste products in unlimited or indefinite amounts for the power-enriched fore-

seeable future. And as Warren Weaver's recent report shows, the price of ignorance in the handling of radioactive materials and devices may be paid by generations yet unborn.

Only if these engineering requirements are well met will new sources of energy, new devices, new materials of construction and manufacture, new possibilities for design widen the horizons of our standard of living! Only thus can engineering continue, in the terms of Webster, as "the art and science by which the properties of matter and the sources of power in Nature are made useful to man." This is our engineering responsibility, something we can no longer neglect! It has had and will have influence on every phase of our profession—on the processing of energy, the processing of materials, and the processing of information.

Accelerating Progress

The intensity and rate of this progress are best illustrated by the steady shortening of delay times between a major breakthrough in science and its application to practice, as illustrated by the phenomenal acceleration in the actual use of atomic energy as a power source. Developments since 1945 have proceeded at a pace and with a uniform success undreamed of then. Already the obvious applications such as the submarine Nautilus and the search for a long-range, high-pay-load missile are being supplemented by experimental stations in city power areas and by plans for military and civilian developments in parts of the earth where fuel-supply costs may be greater than those of reactor installations, or where transport lines might be cut by political or military developments.

To project reactor development beyond the present, we need only look at its possible functions in relieving shortages of fossil fuels. Then we are faced again with the practical tasks of developing the new metallurgies, ceramics, thermodynamics, heat-mass-momentum transfer, control systems, stationary and movable structures of radical types, and many other systems long considered directly and primarily in the engineer's domain.

Our challenge, then, is simply whether engineering education will recognize the existence of Modern Physics research, will survey its extent, and will take swift action to meet the requirements for comprehension and absorption of these new engineering tools. Clearly we can no longer assume that Modern Physics and its research interests are just "knowledge for the sake of knowledge" that will have little effect on the physical world of practical, everyday society.

Bridging the Gap

One demonstration of bridging the gap between physics and engineering has been provided by the communication engineer. Unlike the nuclear engineer, his bridge depended on the fact that, because the processing of information can employ devices which are small, and because the processing itself commonly makes use of electron flow, the communication engineer can easily both apply and participate in modern physics research.

Thus, the characteristics of gaseous rectifiers, the work function in thermionics, and the photoelectric effect were understood better and earlier because of research contributions from Modern Physics. Even here one cannot attribute the invention of either

the photo-electric tube or the gaseous rectifier to Modern Physics, although concepts and leadership from physics greatly assisted their understanding and improvement.

In solid state physics it is natural that the first major practical contributions should have been in the understanding of the simpler materials and the consequences of impurities or defects. Hence the knowledge of the elements germanium, silicon, and selenium has produced the transistor as well as major improvements in rectifiers and detectors. The next advances were in the simple alloys of titanium and aluminum. Developments in magnetic materials to give square hysteresis loops are particularly valuable for computer memories.

As chemistry has provided a wide variety of new organic materials, it seems equally certain that solid state physics will continue to expand the production of new, and the improvement of old materials, both organic and inorganic. While these have been most useful to and therefore studied most by the communications engineer, it is logical to expect that their effects will spread rapidly to other fields of engineering. We must be ready to take advantage of this assistance, as electronics has already done in part, to assure our maximum engineering success for the future.

The Promise

Even more important than the actual accomplishmnets up to date in improved materials, is the promise that such demonstrated progress will continue and will become increasingly important as time passes. New materials not only serve to provide substitutes for existing ones, but insure us against depletion of natural supplies, increasing our independence of natural endowments both in energy and physical resources.

Frequently, too, such synthesized elements turn out to be not merely "just as good," but even superior to the old materials and applications. An example is the development of phosphors for color television tubes. Here, even where the engineering procedure to obtain an approximation of the desired characteristics still required cut-and-try, combined with endless testing, only a comprehensive understanding of solid state physics provided intelligent guidance for experimentation. In the same way, knowledge about the specific effects of both beneficial and detrimental impurities is of the utmost importance in any rational exploration of crystalline materials.

The Engineer's Position

Perhaps the most important effect of introducing the ideas of Modern Physics into engineering education, and of applying them (together with other new concepts such as information theory and high velocity thermodynamics) to engineering practice, will be on the social position of the engineer. One can predict confidently that industry must and will change at an ever greater rate as an outgrowth of new scientific and engineering developments. As the problems become more complex and difficult, ever requiring more profound mathematical approaches, accurate predictions will be difficult to make and must be prepared by experts who understand thoroughly all the determining factors. These experts, in turn, can only function properly if they have a major voice in the determination of policy, for policies also

must change to meet new conditions. Only those organizations whose leaders are alert to these changes will survive. Thus, engineers and scientists must have a growing part in the top management of successful corporations, a trend which has already been observed widely. Because they have recognized this opportunity for greater responsibility, engineering educators are also emphasizing the need for our students to have a broader social and humanistic education.

Status of Engineering

This has been the evolving history of engineering. When the products which could be provided by the engineer were simple and changed slowly, the overall determination of plans could be made by laymen, and involved primarily questions of capital available and of expected profits. Under such conditions the banker, the lawyer, and the politician made the decisions and then hired the engineer to execute them with detailed drawings and designs. This was the basis on which our canals, our railways, and the general industrial expansion of the nineteenth century developed.

Those days are not likely to return, at least if we of engineering education are awake to our responsibilities. To meet this challenge, however, requires that we acquaint our students with the accumulated knowledge of modern research in physics and other fields, and that we keep our faculty members and student bodies abreast of the new sciences. Just how this can best be done must be determined in detail by many groups, and extensive studies are being undertaken with this goal in mind. It is also necessary that they understand through the study of humanities how people have acted and reacted throughout the ages so their decisions and policies may be both humanly and physically practical.

Certainly it is not our present task to discuss ways and means, but rather the general need. The basic impact of research in Modern Physics on engineering education is that of a great mass of essential knowledge which must be economically and efficiently absorbed into all our courses and all our points of view without adding disastrously to our curricular loads. This is more than anything else a question of attitude on the part of engineering educators. Given the will and some direct study-acquaintanceship with research results, plus experience in such research ourselves, a way can surely be found to incorporate what is most valuable without too serious instructional dislocations.

Widespread Absorption

It is doubtful if the immediate next step should be to require of all undergraduate engineers a course or courses in Modern Physics as such, though certainly well-designed offerings should be available for those who wish them. Furthermore, we should surround our students with such an intellectual climate that progressively more and more will elect such courses. But the most productive results will be accomplished by the constant integration of physics research findings into many phases of engineering instruction. They can be incorporated into programs dealing with metallurgy, semiconductors, insulators, control devices, thermodynamics, sanitation, structures, materials, energy conversion, fluorescence, corrosion, wave propagation in various media, and many other areas of importance in engineering theory and design.

Certainly, too, no graduate degree in engineering should be awarded without some content in Modern Physics.

This plan requires that engineering teachers themselves must have a full understanding of the meaning of Modern Physics and its results as applied to their own fields. It has been shown again and again that the most effective way to keep an educator at the forefront of scientific and engineering progress is to have him devoting part of his energy to work at the frontiers—that is, to research. As the line of demarcation between teacher and research worker breaks down, and as our engineering instructor becomes truly familiar with the new concepts by working them into his own problems, he will in turn be able to find the best way of bringing these concepts into the curriculum, through both existing and new courses.

The Soothsayer

Under these circumstances, our graduates will be better able to control the impact of Modern Physics upon our social structure, for the benefit of society and the engineering profession. Perhaps this turn of events can best be put in allegorical form. In ancient days success in battle was deemed to result not only from wise generalship, but also from the design of Fate or the whim of the gods. Prediction or analysis of these conditions was the function of the soothsayer, and all well-equipped kings or generals had such a person as an important member of their staffs. No battle was purposely joined without the assent of the soothsayer.

With the wider acceptance of monotheism, however, God became predictable as always being on the side of the right. The clergy were no longer asked to advise on the conduct of the campaign, but merely to assure the troops that they were on the side of God. Under such conditions, status as top staff members was soon lost.

In modern times, without discounting in the least the importance of ethical and moral grounds for policy decisions, there is an increased need for men who can predict the future accurately upon the basis of sound knowledge. This modern successor of the ancient soothsayer is the informed, socially-conscious interpreter of right under complex scientific conditions which leave the laymen or the uninformed hopelessly confused. A spectacular (and thank God a successful) instance is that of Eisenhower consulting his weather experts before the Normandy invasion.

For the years ahead, if we are wise enough to pick up the gage of Fate, that function of scientific and ethical leadership combined can well be discharged by the engineer. This, too, we might say, is the final impact of research in Modern Physics upon Engineering Education. Given the vision to adopt, use, and continue expanding the knowledge provided by science, engineers and engineering education may well provide the enlightened soothsayers of our technological future!

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SCIENCE AND ENGINEERING EDUCATION

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Before it is possible to consider adequately the specific role of science in engineering education (and I am going to restrict my remarks to the undergraduate level completely) it seems to me essential to try to establish first its role in two much broader contexts:

1. in modern life as a whole;
2. in *any* undergraduate education today.

Failure to clarify these general issues leads to great confusion in the specific case at hand.

What science has done for the life of mankind falls into two major categories:

a. It has provided and recorded *objective and controlled observation* of the world about us, so we may know as precisely as possible *what* happens, and *how* it takes place.

b. It has provided *quantitative models*, called mathematical theories, which represent in a common logical scheme as many as possible of the multitude of observed, and offhand seemingly unrelated, events of nature. This process of model making may be called the *quantitative organization* of natural phenomena. It is usually distinct from, and subsequent to, the first (qualitative) *classification organization* of observed events. It must also, however, do more: namely provide prediction of the quality and quantity of the outcome of observations not yet made, in order that the extent of our observation shall be encouraged to grow from such seeds of suggestion, the possibility of new application be enhanced, and the validity of our theories extended to include a continuously widening scope.

The use of the two techniques described above, in alternate and interlocking sequence, forms what may be called briefly *the scientific method: the controlled observation and quantitative organization of natural phenomena.* It is as important in applying science (doing engineering) as in furthering science itself.

To the extent that the process of any education should, ideally, produce in man a broad appreciation of the pattern of all his surroundings, past and present, it is obvious that the ever increasing domain of science must command an expanding fraction of man's total education. In our present complex industrial society, W. R. Hawthorne [1] suggests that:

"Our education program even for a liberal arts student must include a study of science extended over the years of school and college. I would select physics as the subject because it has the elements of precision and romance which were so valuable a feature of Latin—a subject which is now lost to us as an educational medium. I would tend

[1] "Education for our Industrial Society," Mollie B. Mandeville Lecture, Brown University, April 25, 1956.

rather naturally to emphasize the applications of physics and its history. The study of application, in the form of some aspect of engineering, has the advantage that it relates the abstractions of science to the realities of manipulation. About eight years of physics taken at not too fast a pace is not an unreasonable requirement for anyone who pretends to be an educated man in 1956."

Professor Hawthorne recognizes the need for mathematics in such a program, but he seems to stop short after algebra—which I find seriously inconsistent with the amount of physics he is suggesting. Nevertheless, the general point is clear and well worth making.

There are two other particularly important items for our present discussion which I would like to emphasize from the foregoing quotation.

The first has to do with the recommendation that some application (called engineering) should appear with science in order to relate the latter more definitely to the real world. Here we find what might be called the "dual" of the topic of our own discussion, this dual topic being entitled: "The Role of Engineering in Science Education." The fact is that science and its application (engineering) are not completely separable, either educationally or professionally. Even a potential scientist cannot afford to rest his grasp of his subject entirely upon its philosophical foundations, and the best way to appreciate the implications of a purely scientific principle is often to study its consequences in the form of applications. I quote Hawthorne's example of thermodynamics as a revealing case in point, and marvel with him at the unique relation between the history and content of this beautiful, abstract construct of the mind, and the everyday application of heat engines.

The second item concerns the reasons why physics might be chosen as the logical science to be used as a vehicle in a general education, instead of, for example, chemistry, biology, or psychology. I believe we encounter here *not* necessarily a judgment passed upon the relative importance to life of one scientific field compared to another, but the simple fact that if the perception of quantitative patterns in knowledge is an important goal of intellectual life, and therefore of any education, then that domain of science which appears to have progressed farthest along quantitatively organized lines should be used as a primary illustration.

It is worthwhile to be a bit more specific now about the meaning and objectives of a so-called general undergraduate education. Let me say at the outset that to me an undergraduate education which extends through the Bachelor's degree is basically a *single* concept. This does not by any stretch of the imagination mean that all undergraduate education should be identical, or even nearly so, but it does mean that its primary objectives should be universal.

In particular, I do not put into this class of education one whose primary objective is either the development of a manual skill, or the furnishing of an apprenticeship in trade. Institutions (or branches of them) designed specifically for the latter purposes must, and do, exist at the secondary school level and above, for those people whose talent and intellectual make-up mark them clearly for such work. Nor do I suggest that undergraduate education and apprenticeship cannot

be applied in fact to one and the same individual, as is indeed done either formally or informally in many cases today.

I do feel, however, that all undergraduate education should have for one of its primary objectives *the stimulation of challenging intellectual activity*. To go further, borrowing from the more inclusive words of Dorothy Thompson,[2]

"The education problem is essentially one of *up*bringing, which begins with inspiration to certain habits of conduct, including self-respect and respect for others according to clearly established standards, which must always include industry, love of work, and responsiveness to high aesthetic and social values."

She points out also the danger of the boredom which results because

"The organization of modern life tends to discourage the expenditure of effort by the whole personality, without the exercise of which the human person develops neither mental nor moral muscle."

I also argue on Miss Thompson's side that "modern industry has achieved its phenomenal production by breaking down the work process into a myriad small operations, each of which is largely automatic." Indeed, as the senior Henry Ford told Dorothy Thompson about twenty years ago, "There is no such thing any more as an unemployable person. 'I can employ the feebleminded,'" he said. For my own part, therefore, I cannot assume that a process of undergraduate education is to be judged successful just because it succeeds in furnishing industry with employable people. And, so there will be no doubt about what I have in mind, let me add my belief that engineering education occupies a position in our society today which makes us, its purveyors, particularly vulnerable to being satisfied too well with this as a primary standard.

Now undergraduate engineering education, if it is to exist at all within the framework of the words, means to me, first and foremost, undergraduate education. As such, it must meet in one way or another the very general objectives set forth above. How then does it differ?

Let us be quite frank about it: the student who selects an undergraduate engineering or science education must agree to accept his learning through a special pair of colored glasses. He will have to receive intellectual stimulation, and learn some of the facts of general life, philosophy, and the history of mankind and his thought, through a technically-tinted glass. It takes a somewhat remarkable man to absorb from a thus narrowed spectrum what others absorb in the same time from a broader one—particularly if there is additional very pressing business of learning at hand. It follows that the obtaining of an undergraduate engineering or science education (if one is to exist at all, worthy of the name) is a privilege of the few—not the right of many. I submit to you, moreover, that a great many of the men employed today in so-called "engineering" jobs do *not* need as prerequisite an undergraduate engineering or science education. A really suitable general education (which I have already pointed out should contain a good deal of science and mathematics today—even if it doesn't at present in most schools) would suffice—if supplemented by some on-the-

[2] "The Crisis of the West," The Marfleet Lectures, University of Toronto Press, December 13 and 14, 1955.

job or out-of-hour training for the rather specific purposes involved. Remember that today graduate professional study is always a possibility, often "on-the-job," and I am inclined to believe that any undergraduate who has not in late high school or early college shown quite clearly his ability (not just his inclinations) for creative technical work should be advised promptly *not* to undertake an undergraduate special engineering or science education. He should instead be encouraged to follow a sound, modern, general education, with the idea of special courses or on-the-job study later if he finally does end up, through his interests and opportunities, in technical work of the more routine kind.

What I have been saying, therefore, is that we dare not design a *special* kind of college education specifically for anyone who does not have *both* general college-level *and* special college-level intellectual ability. This is not a new idea—the New England Conservatory of Music is not, and should not be, open deliberately at the regular undergraduate level to those of only casual or moderate concern for and ability in music—even if their intellectual capacity is high and their strong interests such that they may someday own music stores, handle records, or business-manage an orchestra. So it must be with the undergraduate engineering schools: they must *aim* at educating the major contributor to *creative* technical work —the men who will *advance* (not just *reproduce*) the state of science *or* engineering. And, because there are always mistakes and marginal decisions made about people's abilities in their 'teens, it is important that there must be many honorable exits and transfers available from this special stream for those who find they should not, after all, be in it.

Thus we come to the concept which I hold to be undergraduate engineering education: an undergraduate education first, but designed especially for those students who, besides being generally of appropriate intelligence, already show clear signs of the special kind of intellectual capacity required to advance the frontiers of science or engineering. The required special capacity is shown, I would say, primarily by two traits:

a. A persistent interest in *why*, not just *how* or *what*, and
b. A high order of ability in handling the abstract, usually measured by mathematical talent.

This concept, however, cannot be adopted unless it is accompanied by the conviction I have already expressed that much good industrial technical work can, and should be, carried on by those who do not qualify to receive such a special kind of undergraduate education.

In taking the foregoing position, I realize that I have raised some very difficult questions, which must be faced in more detail than I have so far considered them.

First, it may sound as though the only man I am regarding as qualified for an undergraduate engineering education is the one usually considered as "engineering research" material—or, more likely, as a potential scientist. Certainly I agree that such a man would be admirably suitable for these special purposes; but I also believe that engineering in industry should be and would be upgraded measurably if more men of the calibre in question could be attracted into a

wider variety of the jobs where *application* of science is the major objective. In this connection, I once noted with alarm the fact that a very large percentage of the really significant recent *applications* of science were not only conceived, but also quite extensively developed for practical use, by men who were trained as scientists or applied mathematicians, rather than as engineers. From my own field I can cite the magnetron, the idea of radar, much of microwave circuitry, the traveling-wave amplifier, and most recently the ammonia or cesium "clock" and the molecular amplifier (Maser). I could add the transistor, the theory of information, or much of the theory of automatic control, and still not mention important non-electrical developments, like the nuclear pile. I was inclined to believe that this fact resulted primarily from a "superior" quality of the traditional scientific education, compared to the traditional engineering education. In some respects this conclusion still appears to me to be accurate, although it misses nevertheless a large part of the explanation. The fact is that the men responsible for the foregoing developments were of outstanding technical quality to begin with; but a most significant point for me now is that *such men were attracted in their formative professional years to the study of science (or of mathematics), rather than to the study of engineering.* It is certainly fortunate for all of us that they subsequently took an interest in the application of their respective fields, but it does not seem reasonable to rely completely and deliberately upon such random cross-migration of interest to support our future need of creative engineers. Should we not design our undergraduate engineering education in a way which will make it appeal to these men of such great technical talent?

This question itself raises directly three subsidiary ones implied in the concept of undergraduate engineering education as I have presented it above.

1. How shall undergraduate education be handled for those men of technical bent who neither meet the optimum requirements of such an engineering education, nor fall within the (rather large) spread of ability which can profit *acceptably* from its offerings?

2. Isn't this class of men much larger than that previously defined, and isn't it likely that technical industry will continue to have need of them in large numbers?

3. Won't their training force us to formulate simply a different type of engineering education, more like the traditional one, in which the whole question of science and engineering education would again arise?

I would approach these questions by first admitting freely to the relatively large number of these "unqualified" men, and then to the probably great industrial need for them now and in the future. Next, however, I would suggest the possibility that subjecting them to a specialized technical undergraduate education, perforce less abstract, and perhaps to be described as more "practical," than the one I have defined previously, would in fact be a detriment in the long run to them, and to our society as a whole. For to follow any intensive form of such a program would evidently seriously restrict the scope of their general education, and reduce their overall merit as citizens and as

human beings; and, compared with what they would derive from a *good* general education, I doubt whether it would raise by anything like proportionately their usefulness in technical industry beyond, say, the first year or two after graduation. Of course I am forced to presume in this connection that a *good* general education would in the future normally contain at least an introduction to the calculus (perhaps one year), and at least two years of a *quantitatively organized* science (of which physics would undoubtedly be the logical choice). Nor do I feel apologetic about this presumption from any point of view. Upon graduation, therefore, an interested man could have arranged his major to make him familiar with enough general physics and mathematics, plus an (elective) introduction to the elements of one branch of engineering, to allow him to enter a technical job under direction. Specialized further study, apprenticeship, or on-the-job training, could then make him very competent in one area —and he also would have the general background to acquit himself well in the economic, social, commercial, or political areas of his environment. Remember that many college graduates who had practically no previous contact with electrical engineering were converted into quite acceptable electronics officers by less than a year's training during the war. I am not suggesting this particular method as a general one, but it is in some respects an "existence theorem."

The hard fact appears to be that *any* sort of technical work which one could reasonably call "engineering" (as distinct from technician's work, for example) requires for its performance at an industrially profitable pitch more than four years of college-level study in some form or other. In the absence of formal graduate work, industry in most cases absorbs the load by losing money on a four-year graduate for a year or more. The incremental change in this picture produced by giving the undergraduate more special practical engineering courses, at the expense of other things, is likely to be very small—to say nothing of the fact that most technical men do *not* end up doing what they envisioned while they were undergraduates!

Therefore my thesis is that the overall need for engineering manpower must be met from two sources:

1. The men who can perform at least acceptably in rather special types of undergraduate engineering education (let us follow Tustin, and call it the curriculum of a "technical university");

2. the men who have technical interests, and who majored, in a not too concentrated way, in some form of engineering as part of a good general education.

In both cases, additional study time of some kind will be required to make the man perform professionally at his own maximum level, but both types of men will have behind them something we would be proud to call a good undergraduate education.

The topic of our discussion has now become modified, by falling into two parts:

a. the role of science in a general education, and
b. the role of science in the engineering education supplied by a "technical university."

Time limitations force me to regard the first as having been covered by my previous remarks, at least sufficiently to justify my restricting myself from here on to the second part alone.

Evidently, the first problem of the prospective high-quality engineer is to learn the science or sciences which he must apply. Here, however, we must be careful about our words, lest we fall into the misunderstanding created by the automotive industrialist who once gave an impressive talk to college professors emphasizing the importance of fundamental science as a background for his potential employees. Everything was fine until someone asked him what he meant by "fundamental science," to which be answered promptly: "How to press a body frame, of course!"

So let me say what I mean by science here, in the context of undergraduate engineering education at a technical university. I mean any and all branches of knowledge about natural phenomena which have reached the stage of very considerable *quantitative organization,* and I include the mathematics required to understand them. Of course one goes only as far as one can in four years. But I would not, out of *free* choice, leave unstudied at the undergraduate level for any engineer any science meeting the foregoing criterion, and I would, if time permitted, penetrate into each one until the state of clear *quantitative organization* degenerates noticeably. This is a frontier of science, and constitutes a logical stopping point for those interested primarily in its applications.

My reasons for selecting the appropriate sciences in this way are several-fold:

1. They fit the requirements of a general undergraduate education, as previously set forth.

2. When time is limited, a selection must be made; those sciences which are well organized quantitatively are the logical ones from which to expect the major *application,* because the mathematical theory is apt to be sufficiently clear to predict the feasibility of any potential application. Those sciences which are only classification-organized are much harder to apply, because a considerable period of immersion in them is necessary before the data can be absorbed and 'felt' sufficiently to proceed by complete intuition.

Parenthetically, I would also *not* consider teaching at the undergraduate level very much of that part of engineering which falls into the classification-organized engineering art, this part being always (by the nature of scientific progress) of a transient quality, and worth learning primarily to the already committed specialist who must perform at a given date in history.

3. The inclusion of all (or as much as possible of) the quantitatively well-organized sciences in an undergraduate special education would leave the product student in a position of maximum flexibility, both as regards the general methods and concepts of science and the ability to absorb during the rest of his professional life the new quantitative organization which will certainly occur. He is therefore in the unique position of being ready to apply quickly whatever may develop out of current scientific research. This is the key property of the engineering or applied science *leader,* as distinct from the refiner of known applications, and

is becoming a real premium in this day when the time gap between new scientific discovery and its application is decreasing rapidly.

Now it turns out, of course, that four years (or even six, including some high school) is far from enough to cover even those parts of science which are very well organized quantitatively. Thus a selection has to be made of a field of applied science at the undergraduate level. I feel it should *not* be done by teaching more of the corresponding *engineering art*, but by weighting more heavily the corresponding branches of quantitatively well-organized science. For example, both electrical and mechanical engineering students should be grounded thoroughly in advanced classical mechanics—a beautifully well-organized quantitative subject—though perhaps the electrical engineer would study more examples of generalized coordinates, and less of elasticity or deformation theory, than the mechanical engineer. Similarly, in the science of thermodynamics, the electrical engineer might emphasize more statistical mechanics and less classical thermodynamics than the mechanical engineer. There is no engineering student today who should be ignorant of quantum theory, because of the profound effect this has had upon the quantitative organization of the properties of matter—with which every engineer must come to grasp sooner or later. The slant may vary, however, being weighted for the mechanical engineer on the side of mechanical properties of matter, and for the electrical engineer on the electrical properties of matter.

The difference between a potential engineering leader and a potential science leader at the undergraduate level should be largely one of interests. Consequently the science education would emphasize more the *unanswered questions of nature*, while the engineering education would dwell upon *the consequences of the answered ones*, through reference to application. In short, a switch from engineering of one kind into some corresponding branch of science (or vice-versa) after graduation should never be difficult for the man who properly deserved, and obtained, the very special form of undergraduate education which I have called engineering education. For such men, it goes without saying that the maximum of science and mathematics should appear in the curriculum. Certainly four years of each would be reasonable. A rough program outline at the college level might look like the following:

Mathematics	4 years
Physics	4 years
Other sciences (chemistry, and biology, psychology or its equivalent)	2 years
Humanities and Social Studies (including economics)	4 years
Science applications (selected according to area of engineering interest)	4 years

The detailed arrangement of the subject matter, and the manner of stressing especially the *consequences* of science through its applications for the engineering student, will be difficult to formulate; but it will not present us with as much of a problem as accepting in the first place the necessity of the educational approach I have described.

FUTURE ENGINEERING ENROLLMENTS AND THE PROBLEMS THEY POSE

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Presented at the General Session sponsored by ECAC on June 28, 1956, at the Annual Meeting of ASEE

Since 1950 there has been a growing concern over the shortage of engineers. This shortage is particularly serious in view of the needs for engineering and scientific manpower to implement our increasingly technical economy as well as to provide for national security. The untiring efforts of the Engineering Manpower Commission, the recent appointment by President Eisenhower of a committee to study this shortage, and numerous articles in the technical and popular press have brought the situation to the attention of the public. Further, job opportunities for engineering graduates have been considerably in excess of the number of graduates available, with a resulting increase in starting salaries as well as in premium salaries for experienced engineers. All of these factors have brought about substantial increases in engineering enrollment from the post-war minimum in 1951 to date.

This upsurge of interest in engineering and the resulting enrollment increases have been encouraging from the standpoint of the obligations of engineering education to the nation. However, if enrollments continue to increase, there is need for serious consideration of the future and for adequate planning to insure that the high standards of education needed for engineers will be maintained. We must look ahead to (1) estimate the future enrollment potential, (2) make policy decisions about the part that our respective schools will play in providing education for this enlarging group of potential students and (3) lay plans to make available the funds, staff, space and facilities required.

The Present Study

When we at Illinois began to consider such plans to allow for staged recruitment of faculty and construction of buildings over several biennia (on a fifteen-year base, in fact), we found not only our present but our forecast enrollment figures to be startling. This led us into a three-stage investigation, in which we first accumulated comparative data for what seemed to be a typical sample of institutions, including midwest state-supported universities, colleges of engineering in privately supported institutions, and private technical institutes.

These data were then supplemented by comparisons with nation-wide figures both for all engineering colleges and for ECPD-accredited institutions. Finally, we came back to interpret our own circumstances, which we knew best, in terms of the general trends which seemed to be evolving for engineering education as a whole. This, too, will be roughly the order of the present discussion, in which we will move from nation-wide enrollments to our own as an example—one which

may not fit all your cases exactly, but can be adapted as you see fit to your own peculiar circumstances.

With the comparative group of engineering colleges, we emphasized not only enrollment totals and rates of increase, but also changes in enrollments by curricula. For the nationwide analysis, enrollments were considered in terms of population trends, numbers of college-age and older men interested in higher education generally and the selection by such persons of engineering as a course of study. These factors, it was felt, would best define, using available data, the problems which we face both collectively and individually.

The Case at Illinois

The impact of enrollment increases at Urbana was first felt seriously in the fall of 1953, when for the second year we had large freshman enrollments and increasing numbers of transfer students. These occurred in spite of the introduction of higher entrance requirements in mathematics and major revisions in several curricula. By 1954 we were sufficiently confident of the trends to make long-range predictions of the student enrollment and teaching loads for the fall of 1955, for 1956 and on to 1967. Our estimates for 1955 were exceedingly close to the actual enrollment and the teaching loads generated by these students.

The data of Table I and Figure 1 indicate the enrollment trends at the Urbana campus of the University of Illinois (excluding the Chicago undergraduate division, Chemical Engineering and Agricultural Engineering). The increases from 1951 to 1955 at Illinois have brought our enrollment up to and beyond that of the post-war veteran period. Also, the rate of growth, both absolute and in relation to the total University, caused us to give serious thought to the already looming problems of staff, facilities and funds in preparation for still greater increases in the future.

Long-range enrollment studies have been made by our Bureau of Institu-

TABLE I

ENGINEERING AND UNIVERSITY ENROLLMENT ESTIMATES

Fall Term	Undergrad. Engineers	Total Engineers	Enrollment Compared to 1951—Per Cent		University Total at Urbana (10-15-55)	Ratio of Engineering Total to University
			Undergrad.	Total		
1951	1822	2317	100	100	15,145	15.3
1952	2089	2554	115	110	15,464	16.4
1953	2370	2842	130	123	15,797	19.0
1954	2905	3383	160	146	16,866	20.1
1955	3360	3950	186	171	18,075	21.9
1956	3739	4405	205	191	19,150	23.0
1957	4044	4778	222	206	19,550	24.5
1959	4634	5555	254	240	20,200	27.5
1961	5455	6494	300	281	22,785	28.5
1963	5845	6984	320	302	24,250	38.8
1965	6571	7711	361	334	26,500	29.1
1967	7440	8585	408	371	29,100	29.5

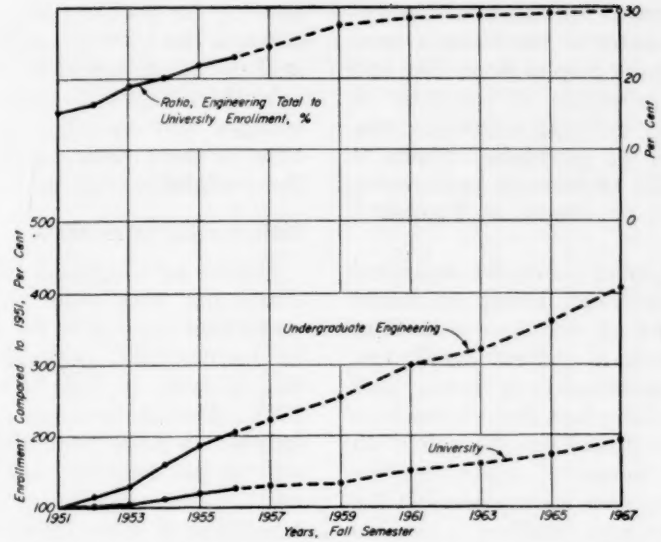

FIGURE 1. Enrollment Increase by College of Engineering and University of Illinois at Urbana.

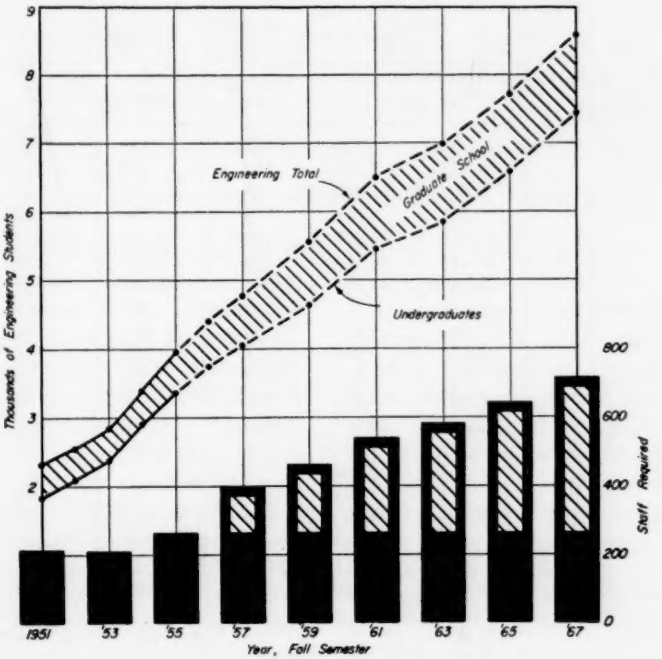

FIGURE 2. Teaching Staff Requirements.

tional Research for the total University enrollments at the Urbana campus. With the help of these data and our own projection of the ratio of engineering to total University students based on established trends, it was possible to estimate engineering enrollments as shown in Figures 1 and 2.

Also, Figure 2 shows the estimated staff requirements based on established ratios of full-time equivalent staff per unit of student enrollment. Mature consideration of future staff emphasizes the fact that as much or more effort should now be placed on ways and means of expanding our staffs as has ever been placed on the student shortage problem. Also, in viewing the problem from the standpoint of our own potential needs for staff, we must look outward and consider the nation-wide situation in both colleges and industry, since conditions in these areas affect materially the availability of staff.

Nation-wide Enrollments

Studies on a national basis (1) indicate that total engineering college enrollment leading to the first degree has increased 51.5 per cent, from 145,997 students in 1951 to 221,448 in 1955. During the same period, the increase in ECPD-accredited schools was 48 per cent for undergraduates and 12 per cent for graduates. A tabulation of these increases by cur-

TABLE II

COMPARISON OF 1951 AND 1955 ENROLLMENT BY CURRICULUM

	Undergraduate			Graduate (M.S. and Ph.D.)		
	1951	1955	Per Cent of 1951	1951	1955	Per Cent of 1951
Aeronautical	3,724	6,326	170	984	933	95
Agricultural	1,523	1,758	115	120	164	137
Architectural	3,601	1,808	50	45	15	33
Ceramics	581	676	116	86	91	106
Chemical	11,576	16,098	139	2,493	2,464	99
Civil	19,744	23,784	120	2,057	2,276	111
Electrical	24,564	45,835	187	5,402	6,481	120
Eng. Mechanics	38	77	202	320	355	111
Eng. Physics	1,366	1,426	104	411	147	36
General	3,050	4,096	134	284	591	208
Geological	938	1,610*	172	89	176*	198
Industrial	5,067	5,991	118	1,511	1,756	116
Mechanical	27,134	39,691	146	3,286	3,475	106
Metallurgical	2,237	2,609	117	759	812	107
Mining	1,267	1,186	94	71	53	76
Naval Arch.	213	185	87	102	106	104
Petroleum	2,534	4,030	159	165	165	100
Sanitary	122	33	27	129	137	106
Textile	616	617	100	29	31	107
Unclassified and others	18,472	32,519	176	984	1,340	136
Total	128,367	190,355	148	19,327	21,568	112

* Includes Geophysical.

TABLE III

COLLEGE-AGE POPULATION, COLLEGE ENROLLMENT AND ENGINEERING ENROLLMENT, 1939 TO 1955 AND PROJECTED ENROLLMENT ESTIMATES TO 1969

Year	College Age[a] (18–21 yr) Population	College[b] Enrollment	Engineering[c] Enrollment	Per Cent College Enrollment to 18–21 Yr. Population	Per Cent Engineering to College Enrollment
1939	9,753,500	1,365,000	108,426	14.0	7.9
1940	9,803,000	1,490,000	113,497	15.2	7.6
1941	9,853,000	1,180,000	114,610	12.0	9.7
1943	9,776,000	965,000	52,450	9.9	5.4
1945	9,537,000	1,074,000	69,680	11.3	6.5
1947	9,273,000	2,333,000	244,390	25.2	10.5
1948	9,036,000	2,410,000	241,554	26.7	10.0
1949	8,805,000	2,456,000	219,712	27.9	8.9
1950	8,685,000	2,297,000	180,262	26.5	7.9
1951	8,567,000	2,116,000	165,637	24.6	7.8
1952	8,076,000	2,148,000	176,549	26.6	8.2
1953	8,002,000	2,251,000	193,333	28.1	8.6
1954	7,968,000	2,500,000	214,414	31.4	8.6
1955	8,081,000	2,721,000	243,390	33.7	8.8
1957	8,296,000	2,820,000	282,000	(34)	10
1959	8,786,000	2,910,000	306,000	(34)	10.5
1961	9,897,000	3,360,000	356,000	(34)	10.6
1963	10,540,000	3,590,000	384,000	(34)	10.7
1965	11,670,000	3,960,000	428,000	(34)	10.8
1967	13,126,000	4,460,000	486,000	(34)	10.9
1969	13,326,000	4,550,000	501,000	(34)	11.0

[a] Data from 1939 to 1951 from Jaracz and Armsby, reference 1. Data from 1952 to 1969 from Thompson, reference 2.

[b] Fall term enrollment. Data from 1939 to 1945 from ASEE, reference 1. Data from 1947 to 1955 from *Biennial Survey*, reference 3.

[c] Fall term enrollment. Data from 1939 to 1955 from reference 3, *Biennial Survey*.

riculum is shown in Table II. It is of interest to note that Electrical Engineering undergraduate enrollment had the largest numerical increase and nearly the largest percentage increase of all curricula. Aeronautical and Petroleum Engineering also had significant increases in percentage of enrollment. Graduate enrollment does not show a substantial growth during this period since the enrollment was not at a minimum point in 1951. In contrast to the trend in undergraduate enrollments, graduate enrollment has increased steadily every year since 1947, with the exception of a slight decline in 1954 which was more than compensated for in 1955.

In order to anticipate future requirements for staff, facilities, and funds, it is necessary to project enrollment estimates on the basis of both past and present trends. The most informative correlation appears to be that between the college-age (18–21 year) segment of the total population, with college enrollments and with engineering enrollments. Data on the college-age population for the period to 1970 have been formulated by R. B. Thompson of Ohio State University in a study conducted for the Amer-

ican Association of Collegiate Registrars and Admissions Officers (2). The college-age population for the continental U. S. from 1952 to 1969, as estimated in this report, is shown in Table III. Data for college-age population from 1939 to 1951 are from the U. S. Office of Education, *Biennial Survey of Education* (3). College enrollment and engineering enrollment are for the United States and its outlying parts for the fall term of the year cited. These data are compiled from the *Biennial Survey of Education* (3) and from the JOURNAL OF ENGINEERING EDUCATION (1).

An analysis of the ratio of college enrollment to college-age (18–21 year) population is of special interest because the projection of this ratio makes possible an estimate of future college enrollment. The ratio has increased steadily from a value of approximately four per cent at the turn of the century to 14 per cent in 1939. The decrease during the War years, 1942 to 1945, was an expected result of the delay in college work for the veteran group. The sudden rise in this ratio in 1947 was due in part to the increased percentage of college-age youth attending college and also to the addition of the veterans who had been delayed during the War years.

When correction is applied for veteran students enrolled (to compensate for the fact that veterans were primarily over the 18–21 year age) the ratio increases more nearly in straight line proportion with time, reaching a value of approximately 21 per cent in 1951. It is felt, however, that under current and projected military training requirements the ratio will continue to be affected by students outside the 18–21 year age group. This sharply increased ratio also results from larger numbers of students remaining in programs of instruction which exceed four years in length, such as graduate study and combination courses.

This trend appears to be a continuing one. For purposes of projecting enrollments, it was assumed that the ratio of college enrollment to college-age population will remain at 34 per cent. This would appear to be conservative in the light of past history. The results of all projected enrollment calculations indicate that by 1969 a total of 4,550,000 students will be attending college. This represents a 67 per cent increase over the enrollment in 1955, which is of the order of magnitude predicted by others, who have stated that college enrollments will double in the period from 1954 to 1970.

Engineering enrollments can, in turn, be compared with college enrollment over the past years with results as shown in Table III and Figure 3. Such a comparison shows that engineering enrollment represented a smaller fraction of college enrollment during the War years even though college enrollments were themselves greatly reduced.

The drop was compensated for in part by the increased percentage in the post-war years 1946–49, and the ratio has continued to increase from 1950 up to and including 1955. An extension of the ratios as indicated by the trends is shown in Figure 3. Values of the estimated future engineering enrollments calculated from these ratios are given in Table III and Figure 3. If one were to be ultra-conservative, a constant ratio of nine per cent could be projected. This does not seem proper, however, in view of the

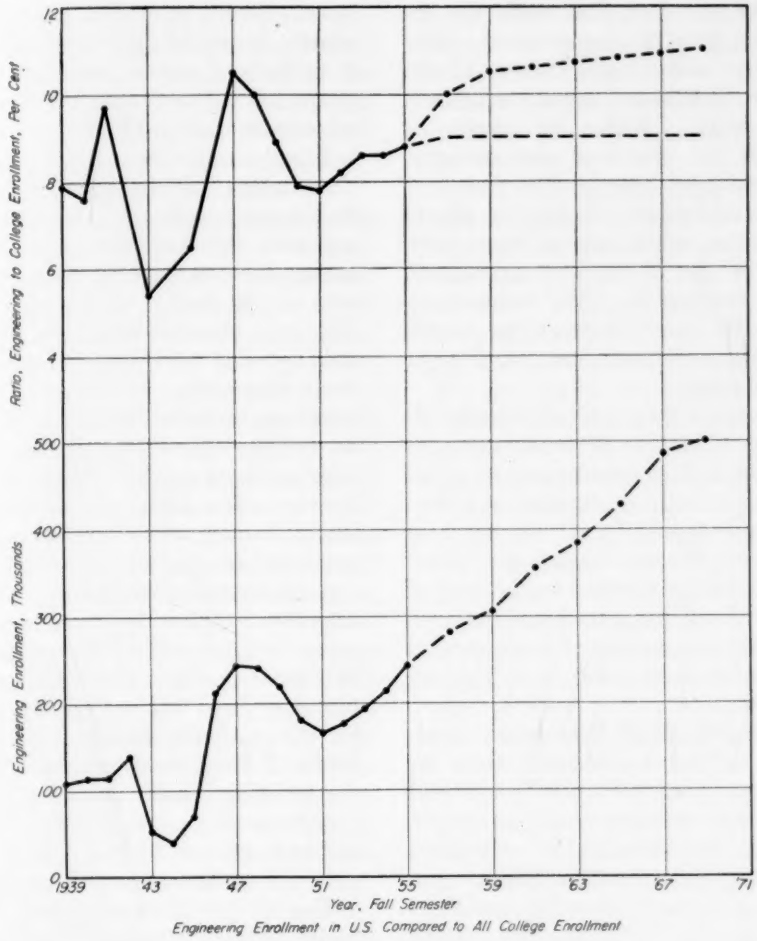

FIGURE 3.

intense interest in engineering by the general public as well as the job opportunities in industry and government which should continue to attract talented young people to our colleges of engineering. On the basis of this analysis, assuming a slight increase in the percentage of choice for engineering, from ten per cent in 1957 to eleven per cent in 1967, we can look forward to 501,000 engineering students in 1969. Admittedly, in the event of a national emergency, it could be less. But my personal feeling is that it will be even greater. In any case, we should prepare ourselves for this possibility, and think ahead in these terms.

The College Problem

What are the implications of this strikingly large projected increase in future enrollments for the various colleges of engineering? First, we must

consider the fact that with the increases already experienced since 1951, the added loads have not been equally distributed among engineering colleges. Either by choice or through the effect of circumstance, many colleges have had increases of 100 per cent or more in undergraduate enrollment, while others have been far below the 48 per cent average of ECPD institutions. The same variation holds true for graduate enrollment, although not necessarily for the same colleges.

It appears, therefore, that each college must analyze its own particular situation and circumstances in order to evaluate fully the impact of future enrollment possibilities. In our case at Illinois, the accelerated growth of engineering in relation to the rest of the University has introduced the need for major reappraisals of requirements in all fields—staff, funds, and building facilities.

Bearing in mind that policy readjustments take considerable time for implementation, we must look ahead at least four to eight years for returns on any combination of planning, budgeting, and execution. This means, in turn, long-range planning now if action is desired in time to meet student requirements and the national need for expansion of our trained manpower reserve. If we wait for future conditions as envisioned here to overwhelm us, the result of efforts to expand will in all probability be too late, whether too little or not.

Even those colleges which choose to establish the policy of not providing for or accepting additional student loads must plan with equal care. They need to develop and perfect wise and equitable methods of selecting and guiding students for the common good. Needs related to shifting popularity in established curricula make it difficult—if not impossible—to force projected student loads into the mold of present staff and facilities.

Finally, regardless of the particular distribution of students among the engineering colleges, we must face squarely the fact that our requirements for engineering teachers will also nearly double in the next 12 to 15 years. As student numbers go up, staff needed will rise in about the same proportion. Our educators have traditionally been trained in the same way as have those who plan to undertake other activities within the profession. For higher education generally, in fact, there has been and is presently no special way of identifying, encouraging or giving particular attention to future teachers as such at an early stage in their student careers. We have perhaps been negligent in our duty here. If we are to provide for the markedly heavier educational loads of the future, we must revise our thinking sharply, and begin to act —particularly by identifying and providing incentives for students with the potential to become good teachers.

The ability of our teachers has a major or even a controlling influence on the quality of our graduates. As engineering educators and administrators, we must take every precaution to maintain and up-grade the quality of our students, even though it becomes necessary to restrict quantity.

This is as important for the well-being of the nation as for that of our profession. The possibility of being outnumbered by the Russians in available resources of trained scientists and engineers is serious enough. It is not nearly as important, however, as failure to develop to the maximum

the creative and analytical minds who provide leadership and technological advancement both now and in the future. Our challenge, then, is to educate with maximum effectiveness as many as we can of our increasing potential student population.

We must give consideration to the development of new areas of engineering education and evaluate their interaction with presently accepted course materials. Nuclear engineering, the application of solid-state science in engineering, and many other developments are making our laboratories obsolete. In some respects, perhaps, a fraction of our staff may be in danger of losing effectiveness, too.

In periods of heavy loads it is often easy to follow the path of least resistance and avoid the introduction of new courses which require the attention of senior staff members. During the relatively short-run G.I. peak this attitude might have been justifiable, but it is certainly not appropriate now in view of the long-range nature of the increases ahead. Stagnation, in order to process larger numbers of students in a hurry, is not defensible today.

Some might hold out the hope that the recent emphasis on humanities and arts will provide engineering colleges with relief in the technical-subject instructional loads for a given number of students. Our own experience in analyzing engineering teaching loads per student has shown that any possible class reduction from humanistic electives is more than outweighed by the increased percentage of transfer students who enter engineering with credit for a large number of non-technical courses. By virtue of this previous work, such students concentrate more heavily on engineering subjects. The result in our case has been, not a decrease, but a net *increase* in engineering instructional loads per student.

In concerning ourselves with the statistical picture of long-range future enrollments, however, we should not neglect a factor which has for a long time reduced our effectiveness and increased our teaching load compared with the number of degrees actually granted. Because proper selection and guidance criteria have been lacking, many students enter engineering who are neither mentally nor psychologically suited to their tasks. This is borne out by the large attrition rate in engineering—estimated at from 60 to 70 per cent of entering students.

Conversely, there undoubtedly are large numbers of college-level students who, with proper preliminary training and counseling, would make outstanding engineers—perhaps even superior engineering teachers. For both of these groups we need better and more accurate direction-finders.

Further Study Advisable

In conclusion, then, we appear to face as a group, though with varying degrees of intensity, a common problem of much greater magnitude than has generally been supposed. Also, our problems threaten us in engineering much sooner than had been assumed, significantly ahead of the rises for higher education generally.

The degree of variation from institution to institution, however, suggests that each of us should carry these studies further, adapting and checking the results for our own local conditions and institutional policies. Though the present forecasts incorporate two to three conservative factors, these might also operate in reverse. Thus, we may face, collectively

as well as individually, burdens considerably greater than indicated now, as well as conceivably somewhat less.

For example, both the duration of time spent in college and the choice of engineering by university-bound students might rise enough to complicate our estimates and add to our loads. These factors especially, which now depend largely on judgment, and for which we have hardly adequate predictive data (how can we evaluate accurately the effects of pro-engineering career publicity of the last few years?), seem to deserve attention.

The theme of our observations so far appears to be probable enrollment increases which demand immediate attention and in many cases drastic action. The individual variations on the theme we must work out for ourselves. In any case, it seems that we should cooperate in finding and training greater numbers of our best students as teachers.

One benefit of this policy would be to avoid overloading (and possibly losing) the competent staffs we now have. Devoting some time to developing and enriching our instructor resources, adding to our available teacher pool, can certainly do good without harm. A specific area of joint action which I would like to see expanded would be that of arranging *exchange programs* for advanced graduate instruction of potential teachers. In this way we could at once gain recruits and avoid the dangers of excessive inbreeding; we could both broaden staff points of view and insure practiced, well-prepared instructors. Cooperation could even be extended to housing and assistantships, which would ease greatly the burdens on young engineering teachers, and might actually attract more graduates into teaching as a career.

In short, our work appears to be cut out for us in terms of nation-wide enrollment prospects and resulting demands upon instructional staffs. It appears, however, that some factors of the selective mechanisms for students deserve closer study, which I suggest should be carried on with a maximum of idea-exchange. Last, it seems that with a cooperative approach by all of us who are most concerned, our problems can be met successfully, and that we can even have a good hope of improving engineering education in the process!

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THE COLLEGE FACULTY CRISIS– WHAT THE COLLEGES CAN DO

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When I first received the assignment to speak on the college faculty crisis, I had read, listened, and thought considerably on the subject. Yet, feeling insufficient to the task, I wrote about thirty-five of my good friends and acquaintances asking for their views. I am grateful to the many who replied.

I am well aware that the problem is not solved as I begin. It will be scarcely more so when I have ended. I hope, however, to review, for your further thought, suggestions already known to you, and possibly add one or two new ones.

President Harold Taylor of Sarah Lawrence College has stated: "A student is the center of education. Schools and colleges exist to increase his intellectual and moral powers. Whatever is done in the colleges and whatever anyone proposes to do must take into account the effect it will have on the student." President Taylor goes on to emphasize that no matter how brilliant or stimulating a teacher may be, he can only provoke students into thinking, stir up their intellectual curiosity and bring them to a point where they, themselves, choose to become scholars.

With this in mind, the real problem before us becomes how best can we maintain and further present effectiveness in engineering education. The faculty is the greatest single factor in this responsibility and since faculty appear to be in ever increasing short supply, we are faced with today's College Faculty Crisis. In thinking of ways to solve, or at least alleviate it, let us keep the effects on students as our sole yardstick for judgment.

The many suggestions I have read and heard plus my own thoughts as to what can be done, divide into two categories: those in which (without outside aid) we help ourselves, and those in which we accept assistance.

Independent Measures

First, let us consider what we can do for ourselves, independently. It ill behooves us to cry for help until we have exhausted all our own resources. Since we pride ourselves on how engineering education develops self-reliance, we are doubly charged with attempts at self-salvation.

While many suggestions as to how we can help ourselves are debatable as to merit and logic, I begin with one that I believe is beyond question. This is that we scream to high heaven about our problem so that the entire nation hears it over and over.

Constantly, I am amazed to find how little the general public, and even close friends, know of affairs that I think are widely understood. I think this because I live so closely with the whole affair myself, talk with

associates about it, even read much about it in the press, yet I find others know little of or are unimpressed by what I think is obvious. They are too engrossed in their own problems to worry much about ours. I suppose they are assuming that we, in turn, know their problems and this is not true either. One correspondent wrote, "the seriousness of the faculty situation as it actually is and as it bids fair to continue, should be publicized with the greatest vigor and all the force we can marshal. This informing of the public I find, in sampling right here on our own campus and in the neighborhood, is really necessary. In a chance conversation at lunch with a local man who should be expected to have some inkling, I discovered that he had only the foggiest sort of notions.

"Last weekend we had our own Development Council and Trustees meeting. Even these men were not really aware of the advanced stage of the malady. I got some very solemn attention when I mentioned some cold hard facts. If such people, who might be expected to be more or less conversant with the situation, are so poorly informed, the general public must be innocent as baby lambs about it."

In short, we should do all possible to publicize our plight, especially by TV and radio. It is a job that the ASEE is especially well fitted to undertake through its officers and committees. You cannot over-sell this problem. Continuous and emphatic repetition is needed.

Another way in which we can help ourselves and which I believe is beyond debate, is to be responsible and sensible, and to refrain from the absurd and ridiculous. I have heard educators bragging about their respective institutions in such ways that an outsider, overhearing it, would think he was listening to a promotional ramble among some of the more irresponsible and lurid publicity men in the movie industry.

Not long ago, I heard a senior administrative officer of a professional college give a very glowing account of his institution that was filled with superlative generalities highlighted by the statement that in his institution, they actually gave six years of education in four. Six years of what kind of education?

Obviously, no educational institution can give more than four years of full measure education in four years. Claims that one does invite comparison with a milkman who advertises six quarts of milk to the gallon. He can only do so by serving short quarts. The educator who made this statement did no service either to his institution or to education in general. Extravagant nonsense can hurt our cause and I suggest we refrain from it in publicizing both college services and needs.

Also let us state our case fully in all areas. In the past twenty-five years, higher education in the United States has added to its responsibilities that of public entertainment. I refer to intercollegiate athletics.

If certain administrators choose to pay athletic coaches more than full professors, that is their business. Likewise, if they choose to give their athletically able students "the full ride" (i.e. all tuition, board, room, books, laundry, and some spending money), that is also their business, but let's be honest about it. When we go to the public at large and say that we can't pay adequate salaries to professors, let's indicate what our basic values

are and their ratio one to another in our judgment.

I am not trying to be sanctimonious. I am the chief executive officer of a college that this year had, if not the finest hockey club in the nation, at least one that can make an extremely strong claim to it. I think I know exactly what it costs us to put this club on the ice and I am perfectly willing to make this information available to all our friends whom we are going to ask for their support. It was made totally available this past year when we were visited by an accreditation team of the Middle States Association. We are not unbalanced.

There are many other areas in which the colleges and universities are supporting delightful and often advantageous fringe programs helpful to a well rounded education. I am not suggesting that they be eliminated or even curtailed. I only suggest that in placing our faculty crisis case before the country, we be honest about our total college budget and where we choose to spend our money.

Instructions on how to solve our faculty problem are many and varied. Overwhelmingly, the simple answer heard most frequently and most loudly is to raise salaries. The solution is poorly stated. In this June's issue of *Nation's Business,* in an article entitled, "Crisis Building Up In College Classrooms," a table is given showing that professors' salaries were raised from less than $4,400 in 1929 to $7,000 in 1953. This is an increase of 75%. The table also shows that increases in the same period for assistant professors were from less than $2,700 to $4,600, an increase of 70%. Instructors' salaries were raised from $2,000 to $3,700, an increase of 85%. Salaries have been raised.

The solution does not lie alone in raising salaries. It lies in raising the relative purchasing power of the faculty member in relation to the rest of society. The table to which I refer shows that in this period of 1929–1953, while the professor's salary was being raised, he actually lost 10% in purchasing power, the assistant professor lost 1%, and the instructor gained just 10%. During the same period, physicians gained 48% in purchasing power, automobile workers 57%, and bituminous coal miners 90%. It won't do much good simply to raise the salaries of professors if, simultaneously, those of the automobile worker, the industrial worker, and other professions are rising at a more rapid rate.

Another closely associated problem is that of increasing the college professor's prestige. While it is more difficult to give a quantitative value to prestige than to purchasing power, it is probable that the community admiration of the faculty member has dropped at least as rapidly as his purchasing power from 1929 to 1955. This is one area in which nobody can help us but ourselves. No government subsidy, no grant from industry, no law can do it.

The problem of raising salaries can be attacked by the colleges alone and also in cooperation with outside agencies. In thinking of what we can do for ourselves, I have already suggested that, if we wish, we can cut out some of the programs not basic to education and apply the money to faculty salaries. This suggests major surgery and I suspect there will not be many takers to this suggestion until things are even more desperate than they are now. But it is possible,

and if we don't do it, let's candidly admit we don't choose to.

Another way that salaries can be raised is by increasing the efficiency of teaching. As with prestige, it is difficult, quantitatively, to assess efficiency in education. Faculty production cannot be measured in dollars or output as is possible in industry. The increase in industrial efficiency is accurately computed; industrial wage increases have kept pace or better, and this advance will continue. While educational efficiency is not so well defined, increases in educational efficiency have not kept pace with those in industry, and much of our problem lies here. The problem is compounded when industry works its manpower 11½ months a year and education in only nine tries to match industry's pay envelope.

Now what do we do? Anything that can be done to increase salaries of faculty that in no way lowers teaching effectiveness, is worthy of careful consideration.

A good area to examine is that sacred cow, the student-faculty ratio. It has long been held that the college with the lowest ratio of students to faculty is doing the best job. But is it? It is interesting to see the gradual, almost timid approach that educators are making in suggesting that this ratio problem be opened to scrutiny. Yet more and more are doing it.

A dean writes, "I get the impression that quite a few faculty members and even whole departments subscribe to the idea that the more time they spend with the student the better educational job they do. As a result, contact hours go up and hence more teachers are required. I feel that we can go a considerable distance in the opposite direction and do a better educational job on our students. Our own staff has done some experimenting in mechanics which indicates that this fetish of small sections is not sacred beyond amendment."

President Malott of Cornell writes in a recent article, "I have never myself been sure that we are correct, in this academic hierarchy, in our worship of very small classes under all conditions and for all subjects."

I believe there is an increased willingness to experiment with larger sections and I have run across numerous references to the studies in this direction that are being undertaken by the Harvard School of Business Administration. I understand they have developed both classrooms and teaching techniques where classes of 100 students can be handled with lively discussions. I think this is one of the most promising suggestions that has come to my attention.

It is but a step from a discussion of small versus large classes to the use of closed-circuit television. Here the idea is to have your cake and eat it too. We still cling to small classes, made by fragmenting a large one. Of these fragments, one has a live instructor and the remaining have a black-and-white image on a twenty-four inch screen. So much has been said about this and so many of you know more about it than I that I will say only that until I see more of it and am impressed by its results, I cannot believe it is more than a very modest tool among the great number we need.

No one seems to have suggested that the neighborhood movie theatre be pressed into service. It could be used for closed circuit TV as it is for prize fights, surgical demonstrations, and sales meetings. It makes available a screen far larger than anything

possible in a classroom. It can be used for educational films as well. (I have often wondered, incidentally, why the publishers of textbooks have not promoted films for sale as they do books.)

Numerous suggestions seem far more radical than the idea of using the neighborhood theatre as an adjunct to a college. We might even make the proprietor an honorary professor and, of course, gain a corresponding reduction in rental rates for the great honor bestowed upon him. I appreciate that a motion picture does not provide a live commentator as does television. But neither does a textbook. There is, though, so much basic information that can be presented by motion picture that I believe there are wide areas where the neighborhood theatre can be used to marked advantage.

Another way in which we can increase the effectiveness of instruction is by assigning our best teachers to those who need it the most. In many areas today, we do just the reverse. Over twenty years ago I remember being midly shocked by hearing a respected professor suggest the best teachers should teach freshmen, and the poorest, the seniors. He concluded by saying that any fool can teach graduate students. Though speaking lightly in the last statement, there is much serious thought in his earlier words. Yet often we find the most skilled teachers and the finest scholars reserved for upper classmen and graduates only.

Several years ago, I interviewed an assistant professor in a large midwestern university as a candidate for a position in mathematics. He told me that all freshmen in mathematics in his institution were taught by graduate students and he was quite sure that this was also true in physics and chemistry. In other words, the students most in need of skilled teaching and inspiration were assigned those least likely to give it, inexperienced young men whose primary interest was their own educational program. This is indefensible and makes no strong appeal to government and industry when we go to them and ask for help while claiming we now are doing our best.

Another way we can help ourselves is to reward merit and not seniority. Those administrators who now have a timetable, which, coupled with degrees, defines what a man will earn at a given period in his career, should throw such a timetable away! I know some of the problems this suggestion carries, but the alternative is both stupid and unfair. It again puts us in a poor position if we ask for outside help and claim we are doing all we can within.

Cooperative Measures

Now let's turn to how we can join with others for aid. All my listening suggests that industry is looked to for help and is willing to help in very many and very important ways.

Many suggest that industry could help the colleges by not "raiding" faculties and also that colleges should not raid each other. (Whoever started the word "raiding" must have been a close relative of the man who invented the question, "Have you stopped beating your wife?" "Raiding" is a poor word.) I take a dim view of this suggestion and frankly hope the day never comes when we will have agreements that prevent so-called "raiding." The suggestion of such an agreement implies that we form a

cartel, un-American to the core. I don't aspire to have in my institution a faculty made up of "slave labor," and this term is just as accurate as the term "raiding." I don't believe that we can attract many teachers of outstanding ability if they come with us with the understanding that, through agreements with other colleges and with industry, they will be denied opportunity to improve themselves by going elsewhere.

Cries of raiding sound suspiciously like plaintive admissions of our own inadequacy. They are pleas for a negative assistance that does little to raise the prestige of education. Like most problems, compromise is required. I hope, however, that industry will feel a responsibility to the colleges from which they wish to recruit faculty personnel for themselves.

The great majority of suggestions of help from industry is concerned with unrestricted cash contributions to the colleges. Then follow suggestions for industrial assistance through scholarship aid, placing of research contracts with colleges, summer employment to professors and the loan of industrialists to faculties on any one of several arrangements. To the suggestion that industry make unrestricted cash contributions to colleges, I have no complaint and I suspect none of you do either. The industrial formula for wise giving is quite difficult and one with which industry is struggling. Many educators are attempting to help, generally with plans that turn out quite favorably to their own institution—a natural and forgivable action.

In offering scholarships, industry has been generous and probably will continue to be more so. It is gratifying that increasingly industry is providing not only full tuition but substantial grants-in-aid that go toward the total cost of education. The opinion appears to be growing among educators, however, that this type of assistance can be overdone and more industrial concern should go for the "poor professor" than for the "poor student," poor financially, you understand.

In some areas, industry can assist effectively by offering faculty summer employment and part time or consulting work during the academic year. This can be very helpful, though it is less applicable for those institutions located far from industry.

It is frequently suggested that industry should lend some of their employees for a year or less to colleges as professors. This has its limitations for, no matter how effective an instructor may be, it takes several years to reach full effectiveness in a faculty program. A long-term arrangement between an industry and a college whereby an engineer might spend part time in each place could be very effective, however.

The foregoing suggestions may hold much promise as stopgap answers to our present crisis. I do not believe, though, that the lasting and complete solution to our problem of faculty crisis lies in them. So long as education charges less than the cost of its product, operates its plant and personnel only nine months out of twelve, increases efficiency questionably, if at all, and simultaneously tries to match wages with industrial competitors which charge full costs plus profit for their products, operate plants continuously, obtain eleven to eleven and one-half months productivity per year from workers, and steadily increase efficiency, education will be the loser and forced into the position of a de-

pendent who, to sustain life, must beg alms from its more productive rivals.

As a basic necessity to the solution of our faculty crisis problem, I propose that education develop some system of financing that at least provides a sum sufficient to cover its full operating costs.

Currently, the student pays the full price of all the various costs of his education except instruction itself. He pays full costs for board and room and for all equipment, books, instruments and the like. He pays the full costs in supplying accessories, including transportation, clothing, incidentals and amusements during his years in college. The one thing he doesn't pay in full for is his professors' worth.

The colleges face a crisis because they are selling their professors' services below demonstrated value. By obtaining higher salaries elsewhere, the professors are only demonstrating what their true value is. The crisis is heightened because there is simply not enough qualified manpower to go around, even if we had money to pay equitable salaries. So we find ourselves competing for manpower in short supply, underpaying it, using it inefficiently and only part time.

What are the solutions? There are several.

One is to have the student pay the full cost of his education. Another is to have taxes supply the money through state or federal scholarships, and this can apply to both public and private institutions. Such state or federal scholarships would permit students to go to any college of their choice, with stipends sufficient both in number and in amount to pay full costs of education, including a decent teacher salary scale. A third possibility is for industry to pay the difference between the costs of the product which they take and that charged the product itself through tuition.

Today industry is unable to hire sufficient graduates from engineering colleges and, simultaneously, is being asked to contribute to the support of these same institutions. Often industrialists state that if they could be assured of graduates, they would be more willing to contribute. Since we do not sign up students as though they were professional baseball players, education cannot make such commitments. Industry can, however, provide financial aid to a promising youngster both by cash loans and in summer employment, and concomitantly can make an agreement with the student whereby on graduation he joins the supporting company. The graduate can then begin to work off his indebtedness to that company at an agreed rate. If he wishes to leave his supporting company and go elsewhere, he would be at complete liberty to do so by assuming his remaining financial obligation with the company that advanced money for his education.

I am proposing that education become financially realistic and with eyes open to the economic facts-of-life, if closed to tradition and custom, attempt to practice what it prides itself in teaching. Until we do, we will continue increasingly to be cast in the beggar's role and it matters little whether we seek alms from legislators or private industry. Public and private colleges are supplicators together.

One last thought and I am done. We hear much about the short supply of engineering manpower and we worry because more engineers are not being graduated. We need to increase the number of new students

entering engineering. Unfortunately, the decision to do so cannot be made by the boy after high school graduation. It has to be made when he starts his high school education. One of the greatest things we can do to help ourselves, industry, and the nation is to encourage every promising youngster to prepare himself for entrance into an engineering college.

I spoke earlier about using common sense in seeking solutions to our problems. I was dismayed to learn that some in high places in university administration propose to help solve the shortage of engineering students by building more engineering educational facilities in an area that surveys show is supplied with such facilities, amply sufficient to meet today's needs and those of the foreseeable future. These people are either determinedly ignorant or unable to understand that the shortage of engineers today results from lack of high school preparedness and not from insufficient facilities.

It is as if picnickers well supplied with pails, upon finding a trickling spring insufficient to furnish water for the group, were to have a member rush up and propose the purchase of a bigger bucket as a solution to the water shortage. The need for finding added sources of water or increasing the flow from the present supply seems to be mysteriously overlooked. We can do better than this and our hopes for aid and prestige demand that we do.

We must bend every effort to find immediate short-term remedies for our basic problem and, simultaneously, to develop a long-range program that will in time give us a complete solution. To this end, we need the most intelligent and the most unselfish thoughts and efforts we collectively can muster.

With help from many of you, I have tried to review the various suggestions for meeting our faculty crisis problem. I want to close with a statement from one who has helped me greatly. He writes: "This faculty problem is a highly dramatic one and because of this, many people are trying to come up with a dramatic solution to it. It is my belief that there is no one answer, no panacea, which will lead to its solution. Instead, we must advance on a number of fronts in many small ways and we must work at this continuously.

"Because the problem posed is so large and challenging, there is a widespread feeling that we 'need to do something.' I think it is quite clear that there are dangers in changes for the sake of change. Care must be taken that we do not undertake projects and experiments simply to prove that we are 'on the job' or just to 'relieve the monotony' or perhaps to show that we are 'progressive.' During the next ten years we will see vast changes in teaching techniques, in operating management methods, in classroom design, and in college financing. This is to be desired, but in the process, while we are talking about doing a quantity job, let's keep an eye on quality also."

THE SCIENTIST-ENGINEER

EARL P. STEVENSON

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My subject is the scientist-engineer –that hybrid gentleman developed in the laboratories and shops of the mid-twentieth century, who may turn out to be the most significant product of our age.

To a group such as this the term scientist-engineer carries little connotation of paradox. But I would remind you that the two elements, engineering and science, have, until very recently, seemed incompatible. The time is not long past when scientists slightingly referred to chemical engineers as plumbers. Nor did pride of profession rest with one side alone. I am sure that most engineers felt vastly superior to those fellows whom they looked on with some disdain, as idlers who left it to the engineers to do the necessary work of the world.

Thus when we talk now about the scientist-engineer, we pay tribute to a revolution that has taken place. World War II catapulted scientists into engineering problems and engineers into situations where new knowledge had to be developed before a problem could be solved. To the amazement of both, this gun-point wedding turned out to be stimulating and fun, as well as tremendously productive. It has proved to be a good marriage.

The children of this marriage are the scientist-engineers of today. During the war, collaboration between scientists and engineers on atomic energy, guided missiles, rockets, fire control systems, and radar was handicapped because scientists and engineers spoke such different languages. Now we are beginning to see the appearance of engineers so thoroughly grounded in science and mathematics that these barriers are slowly being overcome. But we still have far to go. One of the great difficulties is that engineers and scientists insist on using different units of measurement. To be effective in much of their work, engineers have had to learn to think in terms of liters per second, not in cubic feet per minute. The language barrier has grown up through the handbooks, and it will be no easy task to solve this problem in communication. Meanwhile, mathematics has become the common language, and the first requirement of the engineer-scientist is that he be proficient in using mathematics as a real tool.

If forward momentum of our industrial and social progress is to be maintained, we must pay particular attention to our need for engineers who can work closely with scientists and who themselves are capable of making creative contributions at the frontiers of knowledge. This makes new demands on our colleges.

The need for the scientist-engineer is perhaps evident, but let me take a few moments to mention some of the

areas in which engineers are running up against research problems of a fundamental nature.

I think, for example, of the work being done in the laboratories of my own company in the development of tools for low-temperature research. When Professor S. C. Collins of M.I.T. came to us in 1946 with his design for a basic tool for cryogenic research, our job (of developing the cryostat) was a fairly classical engineering assignment. But work on this and subsequently developed low-temperature research equipment such as the magnetic refrigerator has led us into problems of a very fundamental kind. Engineers came face to face with the necessity of understanding the workings of atoms. Quantum mechanics, which up until a few years ago had seemed the purest of pure science, appeared here right in the middle of an engineering assignment. In the course of developing equipment for research at temperatures close to absolute zero, engineers became deeply involved in such problems as those of measuring the thermal conductivity of super-conductors in and out of a magnetic field. They found themselves working in a strange world, where helium acts in such an unusual way that it amounts to a fourth state of matter, since it does not resemble a normal solid, liquid, or gas. In this unmapped world there are no engineering handbooks. Only today are we beginning to build up enough experience in low-temperature research so that it is possible to begin to think about a handbook in this field.

Elsewhere in my organization, fundamental work in atmospheric physics is opening new vistas for engineering. It is conceivable that the time will come when we can control electrical storms. The controversial questions now being raised as to the possible impact of nuclear explosions on weather patterns are reminders that we may be closer to weather control than we realize. The famous remark, "Everybody talks about the weather, but nobody does anything about it," may some day be relegated to the category of eatable words.

Other examples of the engineer-scientist come readily to mind. I think of John Trump at M.I.T., whose work as an electrical engineer, in developing the Van de Graff generator, has led him into research in a wide variety of fields. Only recently he submitted a proposal for a research grant to the National Science Foundation, which the Engineering Sciences section considered engineering research and the Biology section felt should be handled as research in radiation biology. The proposal is in part to investigate the response of an electron irradiated system as a function of the time during which the radiation dosage is delivered, but also "since micro-second irradiation to high dose levels involves also the attainment of high peak electron currents," Dr. Trump states, in his proposal, "a concurrent physical study would be carried out on the factors which influence the attainment of such high peak currents in an accelerating system."

Where does science end and engineering begin?

One thinks of work in radio-astronomy, of interest both to astronomers and communication engineers. One thinks of the collaboration of mathematicians and electrical engineers in developing communications theory and application. One thinks of the closely associated interests of physicists, chemists, biologists, metallurgists

and engineers in nuclear reactor development. One thinks of the jet engineers prodding the metallurgists to produce materials which will withstand heat of 1600° to 2000° F. And so on *ad infinitum.*

Further evidence of the growing involvement of engineers in research problems is the number of professional engineering societies which have research committees. While "research" in such cases can mean one thing to the civil engineer and another to the electrical engineer, it seems evident that engineering interest in fundamental problems is growing.

I think, for example, of the distillation study which is being sponsored by the Research Committee of the Institute of Chemical Engineers, and which is providing grants to three cooperating universities.

Recently I saw a memorandum from the Committee on Research of the American Institute of Electrical Engineers, and because it is so pertinent to this discussion I should like to quote the statement of objectives:

"The Committee on Research," the memorandum states, "is directed by the by-laws to stimulate research of interest to the Institute and to initiate and direct research investigations. It is the considered opinion of the Committee on Research, that the interests of the Institute and the engineering profession and the economic welfare of America are intimately concerned with a continuing expansion of energy availability and that long-range research programs should be encouraged among the electric utilities, manufacturers, research foundations, and educational institutions. This research should endeavor to develop new materials, or knowledge that will be needed over the longer term rather than be concerned primarily with present day operating problems."

In further amplification of this program of objectives, the memorandum points out: "In only thirty years we will require eight times the present generating capacity, nearly a billion kilowatts. Will the present methods of generation, transmission and distribution be adequate to supply the energy requirements at this time? The use of nuclear fuel for the generation of electricity will undoubtedly be an economic reality, but this is only a small segment of the overall problem. Energy must be delivered to the ultimate consumer and in high level density areas the problems of land availability and space and terminal capacity in the street, are already severe. Is there new knowledge as yet undiscovered that may ease this burden?"

The growing concern of engineers with research problems points up the need for an increasing number of engineering students not only to become familiar with the principles of the various fields of science and engineering and mathematics, but also to acquire experience in basic as well as applied research.

It is here that the program of the National Science Foundation takes on significance. For while other federal agencies are giving support in much larger amounts to basic research in the colleges, it is the undertaking of the National Science Foundation to aid the engineering schools in defining their research objectives and creating a research program that is well balanced between basic and applied projects.

The close association of the Society for Engineering Education with

the National Science Foundation program in engineering science has meant that from the start the educational objectives of the engineering colleges have received special attention. Insistence that the Act include support for engineering research focused attention on the evolving role of the engineer as a pioneer in frontier fields. It has sharpened interest in the educational problems of training men to be scientist-engineers, and it has served as a focal point for discussions about the aims of engineering education.

The story may be apocryphal, but I have been told that in the early days of the National Science Foundation, someone said to the Director of the Mathematical, Physical and Engineering Sciences: "There is no such thing as basic research in engineering." His reply to this was, "It is in the Act, and so there has to be such a thing."

The story could be true. I recently discovered, as I was leafing through some files in the NSF office, that some three years after the Foundation began making grants for research in engineering science, the Advisory Panel for Engineering Sciences appointed a committee to define engineering sciences and basic engineering research. That was in June of last year, and so far as I know, the members of the committee have still to reach agreement on what constitutes basic engineering research!

Fortunately the difficulty of pushing and pulling words into an adequate definition has not held up a vigorous program of engineering research grants. Whatever it is, it is being supported! Grants are being made within the broad framework of the NSF purpose of supporting basic science, and whether such basic work is considered engineering research or otherwise is largely determined by the origin of the proposal. Thus a proposal from a chemical engineer doing research in chemistry would be considered engineering research, while a proposal from the physics department in an engineering school would probably be treated as research in physics. As we have seen in the case of the Trump proposal, however, there is no firm policy in this respect.

In the Second Annual Report of the National Science Foundation, the report for the year ending June 1952, NSF policy in respect to engineering science was stated as follows:

"In considering the program of the Foundation in the engineering sciences, the traditional categories, such as aeronautical, civil, chemical, electrical and mechanical engineering do not always provide a framework. The emphasis is rather on research fields common to these disciplines, such as fluid mechanics, strength of materials, corrosion, heat transfer or thermodynamics, because the basic engineering sciences are concerned primarily with the utilization of scientific principles for the general welfare rather than the design aspects of professional engineering. Moreover, the Foundation's program in the engineering sciences, and its research support budget, is being used to encourage research to fill gaps in the basic information now available to the engineer. Special attention is centered on those research projects which are basic to the extension of the use of strategic materials, the replacement of strategic materials with new, hitherto unknown materials, and the better understanding of energy conversion."

If when the NSF program was launched there were those who were still wondering what engineering research was, it soon became clear that

the engineering schools thought they were doing it. Proposals were received in engineering science in an amount equal to almost half of the total NSF funds for that year. Because of the small proportion of funds in relation to proposals, the Division of Mathematical, Physical and Engineering Sciences was able to make grants in an amount equal to only 4.8% of the proposals received. Only three of the 28 grants made by the Division in 1952 went to engineering science. This represented 2.5% of the proposals in engineering science. To state the situation another way, in the fiscal year 1952, 17% of the proposals received by the MPE Division were in engineering science, but only 10% of the grants made by the Division were in this area.

That the quality of the proposals has improved steadily since then is evident. In fiscal 1954, engineering proposals again constituted 17% of those received by the Division, but in that year 21% of the grants made by the Division were made in engineering science. Funds still fell very far short of being able to provide support for the meritorious projects—in fiscal 1954 only $1 was granted for every $4 of meritorious proposals received in the field of engineering sciences.

Even in fiscal 1954 the quality of the engineering proposals was not as high as those in the other MPE disciplines. In that year 79% of the proposals coming to the MPE division were rated excellent or good, while only 64% of the engineering proposals were so rated. By the following year, however, the engineering proposals were above average in excellence. In that year, while 81% of all MPE proposals were rated excellent or good, 83% of the engineering proposals were in this category.

That basic research activity in the engineering schools has been stimulated is indicated by the increase in proposals received for engineering research. In the year just ending, requests have totalled approximately $3,750,000 for engineering research—more than the entire budget of NSF in its first year of operation. In comparison, the Engineering Sciences Program had the total sum of $746,000 for fiscal 1956 available for grants, conferences, surveys and other uses.

We still know far too little about the actual effect of these grants in training the scientist-engineer. It seems to me that this should be the crucial question. Are these grants training men who can do work in basic science or collaborate effectively with those who are? It has been said that basic research by its very nature eludes evaluation. But in respect to its impact on education, I believe we can and should do some very thoughtful evaluation of these projects.

Overall statistics tell us something, but not too much. If our aim is to evaluate the programs in terms of their help to students, we shall want to focus our attention on the students —graduate and undergraduate—who have participated in these projects.

From the Annual Report of the Division of Mathematical, Physical and Engineering Sciences for Fiscal Year 1955, we learn the following:

—The average amount of a grant has increased from $9,943 in fiscal 1954 to $13,271 in fiscal 1955.

—The average duration of grants for fiscal 1955 is 1.8 years, an increase over the 1.7 years for fiscal 1954.

—As in fiscal 1954, about two-thirds

of the grant funds in fiscal 1955 were for salaries.

—About 20.5% of the grant funds, in comparison with 16.6% in fiscal 1954, were for faculty salaries, of which two-thirds were for summer work.

—About 41% of the MPE research grant funds involved research training, viz., post-doctoral associates, graduate assistants and undergraduate assistants. This amounts to $1,693,797 (41.0%) in comparison with $810,724 (41.4%) in fiscal 1954. In fiscal 1955, 498 students participated for a total support of 883 man years.

—About 8.9% of the grants made were for continuing support (i.e. previous grant by NSF) and 10.3% for transfers (i.e. previous support by another federal agency). Of the total funds granted, 50% supported research which had, either by project or principal scientist, a history of previous support by one or more other Government agencies.

It is believed by the staff of the engineering sciences section that most projects in this field provide thesis material, but up until now the grantees have not been asked to report on this aspect of work. Occasionally reports do come in voluntarily. For example, a research project on the fundamental study of plastic flow of metals, "Mechanics of Plastic Deformation of Metals," received a grant of $9500 and was staffed by a principal investigator and two research assistants. During the first year of its projected two-year duration, this project was the subject of three completed masters theses, and five technical papers.

Until now, as I have pointed out, the records do not always include this kind of information. I am curious. I should like to know more about what the contribution to education has been, both with reference to the individual and the institution. I should like to know, too, what happens to the men who have worked as research assistants on these projects. Do they go into industry and become the creative technologists in the border areas? Do they acquire faculty status? Or do they continue as residents in the colleges, developing the art of soliciting grants?

So far in the history of the Foundation we have not been able to get this kind of evaluation because the grants program has suffered from lack of funds. There has been neither money nor staff time for follow-up of this kind. It is also true that since most projects run for more than a year, only a small per cent have so far been completed, and only now are significant data becoming available. (Through September 30, 1955, the Engineering Sciences Program had made 144 grants of which 117 were still active at that time. Only 27 had been completed. The 117 active were distributed in 60 different schools in 37 states and in the District of Columbia.)

It will not be easy to evaluate the impact of these programs on the development of individuals, but I think it is important that we do so. In expressing this thought, I recall the experience following World War I with the National Research Council fellowships financed by the Rockefeller Foundation. The significance of these grants in terms of their impact on the scientific well-being of the nation cannot be over-emphasized. It was from this group that we staffed many of the major research programs of the early 1940's. It is to this group that

we look today for leadership in many fields of science. There is an opportunity to repeat this experience in the field of engineering through the grants program of the Foundation, as well as in its fellowships program.

There is opportunity here, but there is also a danger. As the grants program increases in size, we run the risk that in subsidizing the research programs that will provide training for the scientist-engineer, we may put too much emphasis on organized research and end by making it impossible for the truly creative individual to flourish on our campuses. The larger the sums available for a grants program, the greater will be the tendency to choose big projects almost exclusively, as has happened in the large private foundations.* The team concept has its limitations.

Our problem of setting a proper balance between large and small grants will be simplified if we keep in mind the special needs of the scientist-engineer who today replaces the inventor of former times, for whom intuition and hunch were often adequate guides. For the new scientist-engineer, on the other hand, intuition and imagination must be accompanied by a great deal of discipline, knowledge, and understanding. For this reason his training must include research experience as well as years of formal education in the principles of science, engineering and mathematics. But we must give him this, and still maintain on our campuses an atmosphere in which the special genius of the creative individual can be nourished.

Let me make it clear—and possibly this will come as a shock to you—that I am not necessarily advocating that we produce more Ph.D's. We need to do everything we can to increase the flexibility of our formal academic requirements, so that there is room for the recognition of achievement that does not follow conventional lines. I suggest that we might take a new look at the standard requirements for the doctoral thesis, to make sure that in requiring research results that can be packaged and tied at the end of a very short time we are not diverting the graduate student from more significant research that does not fit the formula. And the same thing is true of the NSF grants program. It should be balanced and flexible, and continually re-evaluated to make sure that it is really doing the job that most needs to be done. Such thinking suggests either a more significant Master's degree or a two year terminal graduate program.

In conclusion, let me express the hope that we do not let our concern with numbers overshadow our concern with quality. The need is great for more engineers. But the most critical need is for more of such as I have styled the scientist-engineer. It is on this comparatively small group of well-educated, well-trained, creative individuals that our technological supremacy in the years immediately ahead will largely depend.

My proposition is that grants in the support of research in the engineering sciences, whether made by government agencies or industry, be primarily concerned with the problem of training more of the kind of engineers needed in the present national emergency.

* See: Dwight Macdonald, "The Ford Foundation," Reynal & Company, Inc., New York, 1956. Also William H. Wyte, Jr., "What Are the Foundations Up To?", *Fortune*, October 1955, and "Where the Foundations Fall Down," *ibid.*, November 1955.

PROJECTS OF THE ATOMIC ENERGY EDUCATION COMMITTEE

Report by the Chairman

PHILIP N. POWERS

President, Internuclear Company
Clayton, Missouri

Presented at the ASEE General Session of the Annual Meeting, June 25, 1956.

Your Committee on Atomic Energy Education was created six years ago under the leadership and through the vision of Dean Thorndike Saville, who was then our President. During this period the Committee has lived through two phases of interest on the part of engineering educators in atomic energy and is now entering a third.

The first might well have been described as an "Is this really necessary?" phase. Those were the days when atomic energy was almost exclusively in government laboratories, still secret, still run largely by physicists, and still concerned primarily with military matters so that the prospects for peaceful or commercial applications seemed dim. The idea that any large fraction of engineering college students should have some acquaintance with nuclear energy matters seemed very remote.

It was in this setting that your Committee organized a series of conferences on atomic energy in cooperation with the Atomic Energy Commission in order to give members of ASEE a chance to become acquainted with some of the problems which were then beginning to be declassified. These conferences, organized on a regional basis in different parts of the country, constituted the first major activity of the Committee. In addition, however, the AEC was urged to prepare a reactor engineering textbook, and with the Committee's assistance the book by Glasstone entitled "Principles of Nuclear Reactor Engineering" was the result.

Next came a "How do we proceed?" phase. Early in 1955, the Committee made a survey among engineering colleges which demonstrated that a strong interest existed in finding out more about the possibilities in nuclear engineering education, what other colleges are doing, and in general what appear to be the best procedures for putting nuclear materials into engineering curricula. Some very tough questions were beginning to come more clearly into focus: How long should the government continue to provide substantial nuclear engineering education? How much of this should the colleges and universities take over, and what equipment would be required? Should specialized courses leading to degrees in nuclear engineering be established, or should the new materials presented by atomic energy be fed into standard courses? What should be the relation between colleges' nuclear education and that provided by industry?

These questions have not been answered, but they have been studied. And to help meet the need of ASEE

members to learn more about how to proceed, several different projects are under way.

First, we made a survey, and we are publishing a report, which summarizes what is now being done in the engineering college atomic energy field and the plans for new programs. This report contains course numbers and descriptions, summaries of special undergraduate and graduate curricula, and non-credit extension courses. For the assembly of these data and the publication of the report for the Committee, we are indebted to Professor Paul Chenea at Purdue. The report is entitled, "Nuclear Engineering Courses in the United States, 1955." Copies can be purchased from the office of the ASEE Secretary.

Second, the Committee has been putting out a monthly "Newsletter on Nuclear Energy," again with the aid of Purdue University. Members and others who wish to be placed on the mailing list for the Newsletter" should write to the Secretary of ASEE.

Third, we are sponsoring two ASEE Nuclear Institutes in cooperation with the Atomic Energy Commission, the National Science Foundation, plus, in one instance, Northwestern University, and in the other, Associated Universities, Inc. Chairman of the Subcommittee on this important project is Dean George Hawkins.

The Institutes run for eight weeks, one at Argonne National Laboratory and the other at Brookhaven. The purpose is to provide engineering college professors with an opportunity to review intensively the developments in nuclear technology and to gain direct experience with some of the laboratory facilities available at these two installations. In all, about ninety participants are expected.

The Atomic Energy Commission is bearing the cost of putting on the Institutes, and the National Science Foundation is providing the necessary stipends and travel expenses. We are indebted to Dr. D. H. Loughridge, formerly at Northwestern University, for administrative help with the Institute at Argonne.

Fourth, the Committee has planned and proposed what has come to be known as a Deans' Conference on Nuclear Energy Technology. Sponsorship in this instance well be jointly with the Atomic Energy Commission, the Oak Ridge National Laboratory, and the Oak Ridge Institute for Nuclear Studies.

Final word regarding availability of funds to support this conference has not yet been received, but we have good reason to believe that the AEC will help out in this matter and that the conference will proceed as planned at Gatlinburg, Tennessee, during this coming September 5 through 8. The Chairman of the Subcommittee which has represented the ASEE in making the plans for the conference is Dean M. E. Farris at the University of New Mexico.

Fifth, a general report on the objectives of nuclear engineering education is being prepared, and it is hoped that it will be ready for final presentation at the Gatlinburg meeting. It is anticipated that this report will analyze several different avenues of activity which are open to those associated with the nuclear industry and the types of training needed by each. Chairmanship of this Subcommittee is held by Professor Glenn Murphy, here at Iowa State College.

These five projects represent major ways in which the Committee has

tried to respond to the needs of this "How do we proceed?" phase.

Now we are entering into a third phase which we may call "big money from the government." One of the jobs of the Committee during the last year has been to advise members of the staff of the Atomic Energy Commission regarding their plans to promote the training of engineers in nuclear energy and the ideas which they have for cooperating with and assisting engineering colleges. The Chairman of this Subcommittee is Prof. Henry Gomberg at the University of Michigan. These AEC plans have not yet been finally approved, and no formal announcement has yet been made. But the program which is being considered is quite substantial, and at the conference which this Committee is sponsoring on Thursday afternoon of this week I will summarize some of the kinds of activities which seem likely to develop with AEC assistance during the next year or two. Also, it is likely that the Deans' Conference at Gatlinburg will be largely concerned with this same question.

Another member of your Committee to whom special thanks is due is our Secretary, Professor Wells Moulton at the University of Washington.

Before closing, I would like to announce another project, which was accomplished by our Ames Program Subcommittee under the chairmanship of George Lobingier. Through the cooperation of the AEC and with the assistance of Professor Glenn Murphy here at Ames, we have a "Pickle Barrel" on display. It can be seen at the Theoretical and Applied Mechanics Laboratory today through Thursday between two and five in the afternoon.

Report of the

FINANCIAL POLICY COMMITTEE

The Annual Report of the Financial Policy Committee consists of the minutes of the meeting held at Iowa State College on Tuesday, June 26, 1956, 8:00 a.m., Memorial Union, The 39 Room. Those present were C. A. Brown, E. R. Wilcox, W. Leighton Collins, and W. R. Woolrich, Chairman. The following recommendations were approved:

1. The balance in checking account should be reduced to a reasonable operating level, as determined by the Secretary, by means of short term investments.

2. Government bonds should be checked for due dates and reinvested in government bonds when due.

3. An emergency reserve fund equal to about three-fourths of one year's operating expenses should be established. It is recommended that about two-thirds of the fund be in savings accounts and one-third in government bonds, but the Secretary should consult with the auditor regarding the reasonableness of the magnitude of the reserve and the reasonableness of the proportions in the two types of investments.

Respectfully submitted,

W. R. Woolrich
Chairman

Survey on

MIGRATION OF ENGINEERING COLLEGE FACULTY BETWEEN CAMPUS AND INDUSTRY

A. R. HELLWARTH

Chairman, ASEE-RWI Sub-committee to Study Cross-Migration between Engineering Faculties and Industry (Assistant to Director of Employment, Detroit Edison Company, Detroit 26, Michigan)

During the past several years, there has been considerable discussion on the engineering college problem of maintaining adequate and qualified teaching staff.

At the Toronto meeting of the Relations with Industry (RWI) Division of American Society for Engineering Education (ASEE) in October, 1955, a committee was appointed to survey one phase of this problem: the loss to industry. On learning that the Engineering Manpower Commission of Engineers Joint Council was also engaged in a survey on the same subject, the committee hesitated to burden busy deans with another questionnaire. Assured by M. M. Boring, ASEE President, that there would not be any appreciable conflict between the two surveys, we proceeded.

The RWI Division commends the deans and their assistants for their excellent response, and thanks them for their cooperation in promptly returning the questionnaires.

A number of comments and suggestions confirm that this subject is of more than considerable interest. Many respondents have expressed a great concern on solving the problems immediately ahead and seem grateful that a group representing industry has undertaken the survey that may open up more discussion. There is certainly a general feeling among educators that industry has a responsibility to share in the solution of this problem.

The Questionnaire

The primary objective of the questionnaire was to determine the losses of teaching staff to industry, and the corresponding gains for the past two school years. To put these figures on a meaningful basis, the breakdown and total number on faculty were asked for by academic rank. Reasons for any losses experienced, the use of retired professors from another college and of retirees from industry, and several other related subjects were explored. To appraise the problem immediately ahead, an estimate of additions needed for the 1956–1957 school year was requested.

These replies could be assembled and analyzed in a number of ways. If anyone does not have his own particular interest satisfied by the following presentation, the committee will be glad to have him raise his question for further study.

In a few cases, we have taken the liberty of interpreting or interpolating

TABLE I

REPORT FROM 93 COLLEGES ON MIGRATION OF TEACHING STAFF BETWEEN CAMPUS AND INDUSTRY
SUMMARY FOR ALL ACADEMIC RANKS BY SECTIONS OF ASEE

	No. of Colleges	Undergrad. Students	1954–1955			1955–1956			Add. Needed '56–'57	Number of Student Assts.
			No. on Faculty	Loss	Gain	No. on Faculty	Loss	Gain		
New England	9	7,500	499	9	3	514	11	7	43	22
Mid. Atlantic	15	18,400	923	37	22	984	28	34	156	98
Nat. Capitol	2	1,800	49	2	1	55	3	1	17	5
Upper N. Y. and Ontario	4	6,200	266	13	3	264	12	3	21	64
Michigan	4	8,200	388	11	4	393	9	9	74	66
Ohio	5	5,400	182	7	4	181	9	6	25	7
Allegheny	2	1,400	60	5	1	60	3	2	20	4
Southeastern	15	22,000	859	46	18	909	42	29	125	77
Mo.-Ark.	2	2,700	95	6	4	98	9	5	22	9
Ill.-Ind.	4	13,000	342	16	11	406	35	13	66	48
N. Midwest	5	12,600	461	17	9	482	38	29	89	59
Kans.-Nebr.	4	5,000	232	9	4	245	8	10	47	25
Southwestern	5	6,500	214	27	15	222	26	22	27	20
Rocky Mountain	6	6,000	205	12	9	223	11	21	45	15
Pacific N.W.	6	6,000	266	13	4	271	14	6	48	19
Pacific S.W.	3	2,800	89	2	5	106	1	6	4	16
Unassigned	2	500	14	1	1	15	3	3	4	—
Total	93	126,000	5,144	233	118	5,428	262	206	834	554

93 colleges are 62% of 150 listed in the 1956 yearbook.
126,000 undergraduate students are 66% of 190,300 enrolled in all colleges as of October 3, 1955.
Using a conservative multiplier of approximately 1.55, the statistics are extrapolated for a national estimate, Table II.

incomplete questionnaires. Any inaccuracies resulting will not appreciably affect the significance of the overall analyses.

Analyses of Statistics

Replies from 93 colleges are included in this report. These are 62% of approximately 150 listed in the 1956 ASEE yearbook. The figures relate to 126,000 or 66% of the 190,300 undergraduate students enrolled as of October 1955.

The statistics have been assembled by ASEE Sections (Table I) and estimated on a national basis by academic rank (Table II). The summary (of Table I) for 93 colleges is as follows:

SUMMARY OF TABLE I FOR 93 COLLEGES

	No. on Faculty	Loss		Gain		Net Loss	
		No.	%	No.	%	No.	%
'54–'55	5144	233	4.5	118	2.3	115	2.2
'55–'56	5428	262	4.8	206	3.8	56	1.0
Two years	5286(av.)	495	9.4	324	6.1	171	3.2

Extrapolating the foregoing by using a conservative multiplier of 1.55, the corresponding estimates for 150 colleges are as follows:

SUMMARY OF TABLE II FOR 150 COLLEGES

	No. on Faculty	No. Lost	No. Gained	Net Loss	
				No.	%
'54–'55	8000	360	180	180	2.2
'55–'56	8400	406	320	86	1.0
Two years	8200	766	500	266	3.2

While it might be suggested that the net loss of 180 (2.2%) for 1954–'55 and 86 (1%) for 1955–'56 is nothing to cause any concern, each dean or department head who has had the unending task of maintaining and improving his staff would say that percentages don't tell the whole story. At the end of two difficult years, the net loss of teachers from campus to industry is extrapolated to be 266.

The losses were at all academic ranks, as will be seen from the following estimate for all colleges:

	2 Year Net Loss	Ratio of Loss to Gain
Professors	52	2.5
Associate Professors	66	2.14
Assistant Professors	90	1.62
Instructors	58	1.22
Total	266	1.54

One dean is also reported as leaving for industry. The larger ratio of loss to gain at the top levels undoubtedly represents a reduction in quality and accounts for a comment by one dean that "It's tough trying to find top-flight men."

By Sections and Colleges

There is no clear cut pattern that would indicate that all colleges in a geographical area experienced correspondingly similar losses.

Upper N. Y., Allegheny, Mo.-Ark., Ill.-Ind., SW. and Pac. NW. had net losses for the two years of 0.08 to 0.06 of their staff. The Atlantic Section as a whole was approximately .01 but one college within this section lost four out of 15 within the two years; two schools within stone's throw of each other varied from lost 3–gained 7 to lost 7–gained 0.

That some schools have had very difficult times can be illustrated by a few losses as follows:

1954–55	7 out of 60 (regained 0)
1955–56	23 out of 130 (regained 19)
1955–56	one department 6 out of 47 (regained 1)

Two sections that would seem to have had no problem, statistically speaking, are Rocky Mountain and Pac. SW.: gaining 7 and 8, respectively. Maybe their agreeable climates and beautiful scenery are an attraction over the smoke stacks of industrial cities!

Private vs. Tax-Supported

Except for a few references by state schools that their State Legislatures had not yet adjusted appropriations to the changing times, there was no indication that either private or tax-supported institutions have had any

TABLE II

MIGRATION OF TEACHING STAFF BETWEEN CAMPUS AND INDUSTRY
ESTIMATES FOR 150 COLLEGES AND 190,300 STUDENTS FOR 1955–56
(Based on reports from 93 colleges)

	1954–1955			1955–1956			Two Year Comparison		Ratio of Loss to Gain	Additions Needed '56–'57
	No. on Faculty	Loss	Gain	No. on Faculty	Loss	Gain	Loss	Gain		
Professor	2,200	45	12	2,240	42	23	87	35	2.5	120
Assoc Prof.	1,750	50	18	1,860	74	40	124	58	2.14	200
Asst. Prof.	2,200	115	60	2,200	120	85	235	145	1.62	450
Instructor	1,850	150	90	2,100	170	172	320	262	1.22	530
Total	8,000	360	180	8,400	406	320	766	500	1.54	1300
%		4.5	2.3		4.8	3.8				

In addition, approximately 850 graduate students (on full-time basis) are used as teaching assistants.

Graduate enrollment	October 3, 1955
For Master's Degree	18,110
For Pre-doctoral Degrees	297
For Doctor's Degree	3,161
	21,568

problem peculiar to themselves. One small private school says, "We have had practically no losses for 10 years; one professor recently was an isolated case, we believe. We do not anticipate further losses." In contrast, another small private school says: "A supply of good faculty is to be had but the price that industry pays is so high that schools like ours just don't have a chance."

One dean from a tax-supported college says, "We have been fortunate in not losing any faculty members to industry in the last 2 or 3 years." Another lost 23 out of 130 this last year. Some believe that their legislatures must increase appropriations to meet competition of other states.

Many other similar observations on the raw statistics could be made; for example, a few replies indicated that the situation is more critical in certain departments than others. Whether or not they are significant enough for the time required is questionable. That there is a problem about which both education and industry must be concerned, there can be little doubt.

Student Assistants

The 93 colleges reported that 554 graduate students are being used for teaching class, laboratory or grading papers. The questionnaire specified that these be reported on basis of equivalent full-time persons. Nationally this would extrapolate to approximately 850.

These are available principally only at those schools and in those departments that offer post graduate study, and that have strong programs to attract good men. In only a few cases was there an affirmative answer to the question, "Do you foresee a sufficient

supply of qualified teachers in this group for the future?"

Physics

"Comment on loss-gain of the physics department."

About twenty schools reported losses, difficulty in maintaining staff, or an immediate need for additional staff. Losses reported were more frequently to other schools and to research organizations. Industry was not often accused of adding to the difficulties of physics departments. It could be readily deduced that engineering is in a much more critical state than physics.

A few references were made by the technological institutes of difficulty in retaining other supporting fields such as mechanics and geology.

Retirees

"Do you employ retired professors from another college?"

16 out of 93	Yes
7 out of 93	Would
3 out of 93	Not yet
6 out of 93	Indicated an age restriction
1 out of 93	Uses own retirees

"Do you employ qualified retirees from industry?"

31 out of 93	Yes (including 1 part-time)
15 out of 93	Would
3 out of 93	Not yet
2 out of 93	With caution or dangerous
7 out of 93	Indicated an age restriction
5 out of 93	Recommend military retirees

Employment of retirees is looked upon by many as an expedient that will help only to solve the immediate problem. The need is greatest for young men who will make a career of teaching.

A number of respondents point out the difficulty of finding retirees from industry who are qualified to teach up-to-date subject matter. Neither is it easy for a person at this age to make the rigorous adjustment to the responsibility of teaching.

Testimony of two deans, however, should turn everyone's attention to this as a possibility: "We have employed 3 retirees from industry in the past 2 years—expect to employ more." "We have had two very successful bits of experience in attracting good engineers from the Army and the Navy." It might be added that very often retirees from the military are available at an earlier age than from industry. Advertising the need may encourage a few early retirements from industry. Such an engineer would in many cases receive a retirement allowance to supplement his college salary and this would later be supplemented by Social Security payments upon final retirement after 65.

Reasons for Losses

"If you are losing—how do your losses compare with normal?"

While the survey has undoubtedly pointed up a serious problem, only about a third of the replies indicated their losses were greater than normal; a few less; and about half estimated them to be about normal. There have always been losses from faculty to industry; the problem seems to relate more to the shortage of manpower to meet the total needs of the country.

"Is industry 'recruiting,' or faculty making first overtures?"

Industry	15
Faculty	26
Both	26
Don't know	11
Industry is not	3
Government	1
Hard to tell after summer employment	1

Comments on this point vary from one extreme to the other. One says "An individual company cannot be blamed for hiring a faculty man. Colleges must become competitive with financial and non-financial incentives for equivalent talents. Perhaps the right of free education for everyone is in conflict with all the other goods and services which are not free."

Certainly all of us in America want the benefits of our competitive enterprise system and of free choice of such an important aspect of our lives as the job we work at.

One comment that suggests a kind of industry-education relationship, we surely all are anxious to avoid reads as follows: "Our one loss was a case of deliberate banditry by a large industry. Our man was under oral contract to return. This is a lack of ethics by industry."

"In your opinion, what is the chief reason for your losses?"

On this, there was more unanimity of opinion than on any other question. Yes, you have guessed it—salary!

73 out of 93 (80%) believe that salary differentials between industry and education are the primary reason for their losses. In several cases, faculty left for 50% to 100% increases in salary. Such differences are difficult to compensate for—especially if there are other factors that might also have an influence.

Among other reasons were the following:

Better position and increased opportunity	6
Other reasons (not specific)	5
To get industrial experience	1
Doctoral requirements	1
Fewer hours of work	1
No time for research	1
Desire to do consulting	1
Housing	1
Wife wants to return nearer her home	1

One former teacher and dean who left the campus several years ago believes there are reasons that may not generally be spoken about. If there is any truth in what this friend of education says, a further appraisal of such conditions should be undertaken:

"I am referring to a great number of engineering college faculty members who have left teaching, not primarily for more money but because of the fact that they have been unhappy about certain conditions which obtain in the colleges and in engineering education in general. I know quite a number of people who have left for these reasons but I suspect that if you wrote to the colleges they would say that all of these people left because of higher salaries which industry is offering."

Those of us in industry who interview engineers leaving the employ of our companies, know what this man is talking about. There are many reasons why employes seek a change other than more money, and our colleges certainly are not free of any of the responsibilities that the employer must accept for good employee relations.

Additions needed for '56-'57

This survey would indicate that approximately 1300 additions to teaching staffs are needed this next year. Opportunities exist for 120 professors, 200 associate professors, 450 assistant professors and 530 instructors.

The total number of faculties of all colleges increased by about 400 for fall of 1955. Taking into account the net loss to industry, about 500 new teachers had to be recruited from all other sources. The job for 1956 will be over two times as great to recruit 1300, indeed, almost three times.

These positions obviously cannot all be filled by engineers who have recently completed master's and doctor's degree work.

One dean has so aptly summarized the situation as follows:

1. The offers graduates are now receiving have coaxed away the bulk of the few men who believe they would like teaching.
2. Staffs must be materially *expanded* during the next five years or classes even at the undergraduate level will be grossly neglected.
3. Practically all new men *must* come from industry. That is where they go upon graduation.

Comments and Suggestions

A number of comments and suggestions were made that are summarized in the following. Some of these propose further study or action on the part of ASEE.

1. Colleges must do all they can to compete salarywise and to make teaching attractive enough to compensate for any remaining difference. More rapid development of individuals and faster promotions may account for some of this; increased efficiencies through improved teaching methods may make possible higher salaries. The problem of differentiation on the campus between technical and non-technical teachers' salaries and the need to enlighten state education departments and other controlling agencies were mentioned.

2. A few have criticized the doctoral requirements now in effect for promotions. More outstanding students will work for advanced degrees if they can be employed as full-time instructors during this period of study.

3. A central agency such as ASEE is proposed for recruiting, development of outstanding students, and interchange between colleges. This same agency might be responsible for "indoctrinating in the joys and satisfactions of a teaching career, and for helping those colleges that have undergraduate programs only and have no direct contact with the post-graduate students."

4. Losses are related to a desire for more industrial experience because of statements in final report of Grinter Committee; reference report, June 15, 1955, pages 6 through 10. Is this realistic when one considers that increase in population will require more engineers in industry, and increased enrollment in engineering colleges will require more engineers for instructors. The supply of instructors in engineering needs a thorough study.

5. Industry must help with the problem or enrollment will be restricted. Some suggestions are:

   a. Compensation for graduate assistants to keep them on the campus.
   b. Collective study of the problem that will lead to collective action and to elimination of competitive bidding for qualified teachers.
   c. Establishment of "chairs" and industrial subsidy (without strings) for key professors. (The ethical implications of this and the effect on other colleges and departments of a university should first be carefully explored.)
   d. Support of research on the campus that would provide extra compensation for teachers.
   e. Industrial consulting, summer jobs, one-day-a-week employment, and other services that will

provide enough financial incentive to keep good men on the campus.

In closing, to say the least, the survey highlights a problem that has generally been recognized as one. It emphasizes the need for action. In the words of one dean: "The picture changes daily—and rapidly! We need salary help or else."

If help is not forthcoming to our engineering colleges, the quality of teaching will suffer and number of graduates will be fewer because of reduced enrollments.

One dean concluded: "At a loss for solution." Undoubtedly he is not alone in this feeling of frustration, but this problem is one that can be solved effectively if industry and education will roll up their sleeves and tackle it together.

Acknowledgment

In addition to those in colleges and universities who assisted in making this presentation possible, the author wishes to acknowledge with appreciation the many who assisted in their ASEE capacities. Most notable among these are those who served with the author on the sub-committee: John A. Hill, Minneapolis-Honeywell Company; Arvid F. Jouppi, General Motors Corporation, Detroit; Stanley M. Little, Boeing Airplane Company, Seattle, Washington; and J. J. Thompson, Worthington Corporation, Harrison, New Jersey.

Report of the
PUBLICATIONS COMMITTEE

The Annual Report of the Publications Committee consists of the minutes of the meeting held at Iowa State College on the veranda of the Electrical Engineering Building at 4:00 p.m. on Thursday, June 28, 1956. Present were G. W. Farnham, E. C. McClintock, Paul Fatout, and W. Leighton Collins, Chairman. The primary topic of discussion was the JOURNAL OF ENGINEERING EDUCATION and the many suggestions made regarding modifications. No specific actions were taken, but there was a common agreement on:

1. The general trend of changes made to date, making the JOURNAL more readable, more newsy, representative of *all* units of the Society, and of greater appeal to all members, should be continued.

2. Plans to include a "Mechanics Division Section" to replace the Division Newsletter should be developed and put into effect on a trial basis. The material for the "MDS" is to come from the Division.

3. The basis for distinction between what should go into the JOURNAL and what should go into a Divisional publication should continue to be as follows:—"Papers of general interest to most divisions or pertaining to topics cutting across interests of other divisions belong in the Journal; papers wherein the material is essentially "shop talk" between or among members of the Division and of interest

only to them should be in the Divisional publications."

4. Devoting certain issues exclusively to papers of a specific Division was considered undesirable because of the limited reader appeal.

Written comments on the four points mentioned above are solicited from the committee members unable to attend the meeting; other items believed worthy of consideration also should be mentioned.

Respectfully submitted,

W. LEIGHTON COLLINS
Chairman

Annual Report of the
RELATIONS WITH INDUSTRY DIVISION

The year terminating June 1956 found the efforts of the Relations with Industry Division divided equally between current projects and the establishment of a permanent constitutional form that would encourage the growth and operation of the Division.

I. Meetings conducted by the Division (not including project committees) were:

June 22, 1955	Executive Committee	Penn State College
July 26, 1955	Executive Committee	Detroit, Michigan
October 12, 1955	Steering Committee	Toronto, Ontario
October 12, 1955	Executive Committee	Toronto, Ontario
January 25, 1956	Steering Committee	Milwaukee, Wisconsin
January 25, 1956	Executive Committee	Milwaukee, Wisconsin
January 26, 1956	College-Industry Conf.	Marquette University
June 26, 1956	Afternoon Session	Panel Program, Ames, Iowa
June 26, 1956	Dinner Session	Joint with Cooperative Division
June 27, 1956	Afternoon Session	Joint with Evening Engr. Education
June 27, 1956	Dinner Session	Business Meeting and Election

II. Subjects discussed in these meetings included:

1. Humanities and Engineering.
2. Migration of Personnel between Engineering College Faculties and Industry.
3. Why Industry likes the Co-op.
4. Evening Engineering Education and the Industrial Community.
5. Current problems and projects of the R.W.I. Division.

III. Committees appointed during the year were:

1. Continuation of Constitution Committee.
2. Preparation of Manual for the Establishment of Local or Sectional R.W.I. Committees.
3. Publicity.
4. College Industry Conference 1957.
5. Survey of Migration of Personnel between Engineering College Faculties and Industry.
6. Annual Program 1956.

IV. The permanent form of the R.W.I. was studied, discussed, and reorganized during the year. Some of these changes consisted of making the Steering Committee the working, legislative body, with the Executive Committee operating as its name suggests. Permanent duties were assigned the Vice Chairman and the recommendation made that he normally advance to Chairman. The Vice Chairman's responsibilities would include the coordination of all local and sectional R.W.I. Committees and activities. These changes and several others were included in the revised Constitution.

V. Projects completed during the year included. . .

1. Printing of the Manual for the establishment of local or sectional R.W.I. Committees.
2. Presentation of Constitution for approval at Annual Meeting.
3. Survey of Migration of Engineering Personnel.
4. College-Industry Conference at Marquette University.
5. Permanent relations established between the Southwest Section, the Southern California Section, and the National R.W.I. Committees.
6. Starting of local R.W.I. groups in Detroit and the Twin Cities in connection with the ECPD Five Year Program.

In addition to these activities, officers of our division appeared on programs of the ASME, the NSPE, and the program of the Iowa Engineering Society. Members of R.W.I. were also active on the ECPD Training Committee and the Ethics Committee of the ASEE. Our officers also met with the Evaluation Follow-Up Committee of the ASEE in connection with their program.

Submitted in behalf of the R.W.I. Division,

WENDEL W. BURTON
Chairman

Report of the Committee on Ethics

ETHICS IN A CHANGING ERA

There is bound to be disturbance whenever aggressive but comparatively inexperienced men encounter veterans who have built up a set of viewpoints and standards over a period of years.

Interviewing Problem

This is the situation we have in the business of interviewing seniors for engineering jobs. It has come to a head during the past year, principally in recent months.

For representatives of employers to visit colleges and to talk to seniors about jobs is nothing new. A few distinguished American engineering companies have been doing it for fifty years. One could name twenty-five corporations which are known throughout the nation for excellent products, stable policies, and long and successful careers. Most of these corporations have had extensive experience in the hiring of graduating engineers. Their personnel officials meet frequently and understand each other. The relations of these officials are on a first name basis. By association and experience, they have worked up policies and attitudes about interviewing students. They consider their policies and attitudes good, and they are exceedingly loyal to them. These policies and attitudes are partly formal and expressed in writing, and partly understood and implied.

In the meantime, engineering industries have expanded prodigiously and new companies have come into being. Before World War II they were obscure or did not even exist. The new companies are aggressive and enterprising. They have accepted vast commitments both in manufacturing and in research. They feel the shortage of engineers as much as other employers, or more so because they lack background and prestige. It is their custom to solve problems directly, and sometimes ruthlessly. They need young engineers, so they go to the colleges to get them. Their interviewing officials are new in the business; they must hire graduates, so they hire them by whatever means will accomplish their purpose.

Since the beginning of May, engineers, corporation officials, and educators have complained to the Committee on Ethics about the tactics of a number of "recruiters," especially some of those who are new in the field. Complaints come in by telephone and in writing, from different sections of the country.

It does appear that many interviewers have done things which are not in good taste. Interviewers have "over sold," and have provided "elaborate entertainment" for applicants. They have failed to give students a true picture of the industries they represent. They have otherwise violated the "Ethics of Interviewing Procedures" adopted by the Council of ASEE in October, 1948, and published in the JOURNAL OF ENGINEERING EDUCATION in March of the following year. Furthermore, there have been violations of the spirit, if not the letter, of the Canons of Ethics of ECPD. Employers have offered bonuses to students who had already committed themselves to somebody else. Seniors have been invited to visit the head-

quarters of employers when those employers knew, or could know, that the seniors were already under contract to their competitors.

Possibly these interviewers and employers have not all been subjectively guilty. New corporations which came into being, and old corporations which expanded, had to develop their organizations as best they could. There are doubtless vice presidents of engineering who have never heard of ECPD or of the Canons of Ethics. Non-engineers have become engineering interviewers. They know nothing about the "Ethics of Interviewing Procedures." Indeed, there may even be members of the Society who do not know that there is an interviewers' code. On the other hand, there are probably a few interviewers who know full well how to conduct themselves but have deliberately disregarded all the rules of the game.

It would be inappropriate in this statement to go into the situation in detail as to names, dates, and places.

The Committee on Ethics proposes to look into the difficulty. After a thorough review, the Committee hopes to propose a workable solution. The Committee may sponsor a meeting of college placement officers, interviewing representatives from the industries, and others concerned. In such a meeting it might be well to listen to all complaints. Each complaint could be studied in the light of the ASEE interviewing code.

It may well be that some of the new generation of interviewers do not actually violate the ASEE code. Perhaps they are merely out of line with commonly accepted standards of good form. In that case perhaps the Committee should propose to the Society the addition of new elements to the Ethics of Interviewing Procedures.

The Committee believes that the prestige of ASEE, of many of the nationally known engineering corporations, and of the American colleges of engineering, is considerable. When all these unite in support of a code of interviewing procedure, few employers will care to defy the code.

In any case the Society, and the Committee, should bring the code, even in its present form, to the attention of engineers, educators, employers, and students.

In this whole business, the Committee on Ethics must remember that not every aggressive person or measure is unethical. The Committee must keep in mind the principle that enterprise always irritates at least some people. It is at least possible that some interviewers have complained to the Committee only because they have been outwitted by recruiting devices which, however, are altogether legitimate.

Undertakings

When the Committee was first appointed by President Woolrich, it adopted as a major objective to make engineers think about ethics, particularly engineering educators, and to keep them thinking about ethics. Council of the Society approved this objective. The Committee believed then, and still believes, that it is better, under present conditions, to keep the question alive than to attempt to produce the kind of authoritative account or report which closes a discussion.

The engineering profession is concerned about ethics. At least thinking engineers and educators are. At the moment, engineering sciences, research, and advanced technology are very much in the fashion. The contents of professional journals, agenda

of engineering meetings, and even popular magazines, radio, and television all testify that the scientific phase of engineering has captured the attention of the profession and of the public. Science and research could be expected completely to crowd from the scene such abstractions as engineering ethics. But science and research have not overwhelmed ethics. Engineers and engineering educators continue to think, talk, and write about ethics. For instance, the American Institute of Electrical Engineers has gone so far as to project a handbook on ethics to be distributed to the membership. The National Society of Professional Engineers is considering a similar undertaking, and has organized a national committee to review cases involving violation of ethics. Such interest, in spite of the prevailing enthusiasm for science and research, seems to indicate that the profession considers ethics a major issue.

In its meeting of June, 1955, the Committee set for itself a number of projects, most of them long term. But the Committee overreached itself; it was unable actually to undertake and complete most of these projects. They involved too much detailed work.

However, the Committee did successfully complete one project. The Committee cooperated with ECPD in arranging a program on the topic of engineering ethics for the annual meeting of ECPD at Toronto, in October, 1955. ECPD gratefully acknowledged this cooperation of the Committee and passed a resolution endorsing the Committee's work. This resolution was published in the JOURNAL OF ENGINEERING EDUCATION in March of this year.

Cases in Ethics

But the Committee did make satisfactory progress in its principal project. The Committee plans in time to propose to the Society the publication of a manual or a case book in ethics. The canons and codes of ECPD and of the several engineering societies are not suitable material for the teaching of ethics in the colleges of engineering. They are merely bald statements of maxims. They serve to guide the engineer who confronts a problem or a difficulty in ethics, but they have no appeal for the engineering student who should learn something about ethics although he does not face a personal ethical problem.

The Committee is of the opinion that ethics can be taught effectively only with the help of specific cases or situations, preferably from actual life and practice in engineering. To explore such cases in the light of canons and codes is, by common consent, an appropriate technique for teaching ethics. A manual or case book will be invaluable in the teaching of ethics, regardless of the teaching method. Some engineering educators prefer formal courses in ethics. Others favor lectures, and still others prefer conferences with student groups and meetings of student societies. But all of them will welcome a manual in which specific problems are presented, and perhaps even analyzed.

During the past year, the Committee has gathered data for such a manual. The Committee has written to officers and Council members of ASEE, to deans and professors known to be interested, and to a few others. These have been asked to send to the Committee information on particular cases or problems which have come to their attention.

A considerable number of cases have been proposed. For instance:

(a) If the codes of ethics require an engineer to share technical knowledge with his fellows, how can it be legitimate for an employed research engineer to keep in confidence the results of his researches?

(b) Is it proper for an employed sales engineer to recommend to a customer the purchase of a competitor's machine when the engineer is convinced that the competitor's machine meets the customer's requirements more nearly than his own company's product?

The Committee will now extend the correspondence to the secretaries and committees on ethics or professional practice of the engineering societies, officials of important engineering corporations, state boards of engineering examiners, editors of technical journals, and others who may have information about violations.

Activity of the Membership of the Committee

During the year, members of the Committee have actively promoted interest in ethics among engineers, engineering educators and students.

In particular, members of the Committee have published one article on the subject of ethics in the JOURNAL OF ENGINEERING EDUCATION, one in the *Civil Engineering Bulletin* and two in the *Bent* of the Tau Beta Pi Association. Furthermore, members of the Committee have delivered addresses on ethics, and on topics comprising ethics, before:

Two sessions of ECPD during the annual meeting at Toronto in October of last year.
Seven student groups in colleges and schools of engineering.
A session of the Civil Engineering Division during the annual meeting of ASEE in June, 1955.
A meeting of a state branch of the National Society of Professional Engineers.
The national convention of the National Society of Professional Engineers.

Acknowledgment

The Committee hereby expresses its deep gratitude and appreciation to the officers and Council of the Society, to their correspondents, and to many engineers and engineering faculty members for their encouragement and assistance. The work of the Committee has always been pleasant and stimulating because of the cooperative attitude of all with whom the Committee has done business. Without such support and encouragement, the Committee would be helpless.

The Committee on Ethics

F. T. Agthe
T. A. Boyle
W. W. Burton
A. N. Carter
N. A. Christensen
R. Emerson
P. M. Ferguson
J. H. Foote
C. J. Freund, Chairman
J. W. Graham
L. Helander
E. F. Obert
S. P. Olmsted
R. L. Peurifoy
L. E. Rich
W. F. Ryan
C. F. Savage
J. Snell
W. C. Van Dyck
R. W. Van Houten

THE COMMITTEE ON RESOLUTIONS

RECOMMENDS that the Society adopt the following:

The American Society for Engineering Education desires to express its deep sense of appreciation to the many persons who have contributed to the outstanding nature of its 64th Annual Meeting.

We are indebted to President James H. Hilton, of the Iowa State College, and to the members of his staff for their cordial welcome, and for the splendid arrangements they made for our comfort and convenience (including housing and meals), and the orchestra, chorus, band, and other forms of entertainment.

We acknowledge a special debt of gratitude to Professor L. O. Stewart, General Chairman of the local committee in charge of arrangements for the meetings, and to all staff members of the college who have served on so many committees and have made such effective arrangements for the great number and variety of events which collectively constitute the Annual Meeting of ASEE.

We are especially grateful to Mrs. H. M. Black, Chairman, and to all of the ladies on her committee in charge of the Women's program, and to Mrs. I. F. Sandfort, Chairman, and to the ladies on her committee in charge of the Young People's program, for the splendid arrangements they have made for the comfort and pleasure of our wives and children.

The Society offers its thanks and commendations to the national officers, Council members, Division and Committee chairmen, and others responsible for planning and conducting the technical sessions, and to the many speakers whose generous contributions of time, energy, and experience have resulted in outstanding programs that are destined to make a notable contribution to the advancement of engineering education.

The committee is humbly grateful for the initiative displayed by the local committee in breaking the long-established tradition of the Society—that the argumentative heat engendered in the meetings be matched by the local weather. We sincerely hope that the committee's accomplishments will establish a new precedent which will be followed by future committees.

The committee further recommends that the Society direct that these statements be spread upon the official minutes of its Sixty-Fourth Annual Meeting, and that copies be sent to all persons mentioned in these statements.

Respectfully submitted,

HENRY H. ARMSBY
S. C. HOLLISTER
LEWIS K. DOWNING
Chairman

SOCIETY COMMITTEES, 1956-1957

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ANNUAL MEETING: C. A. Brown, *Chairman,* General Motors Institute, Flint, Michigan; W. L. Collins, J. C. Gebhard, K. L. Holderman, S. C. Hollister, E. D. Howe, L. O. Stewart, L. M. Vallely.

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AWARDS PROCEDURE (*ad hoc*): N. W. Dougherty, *Chairman,* University of Tennessee, Knoxville, Tenn.; W. T. Alexander, R. J. Woodrow, R. M. Campbell.

CONSTITUTION AND BY-LAWS: C. A. Brown, *Chairman,* General Motors Institute, Flint, Michigan; H. H. Armsby, T. A. Boyle, Jr., H. O. Croft, L. K. Downing, K. B. McEachron, Jr., H. P. Rodes, K. F. Wendt.

DEGREE DESIGNATION IN COLLEGES OF ENGINEERING AND TECHNICAL INSTITUTES (*ad hoc*): J. H. Sams, *Chairman,* Clemson A. & M. College, Clemson, South Carolina; T. J. Higgins, K. L. Holderman, S. C. Hollister, H. K. Justice, C. O. Mackey, H. P. Rodes, L. F. Smith, J. F. D. Smith, J. W. Whittemore.

DIVISIONS AND CURRICULAR ACTIVITIES: C. A. Brown, *Chairman,* General Motors Institute, Flint, Michigan; Chairmen of all Divisions, Chairmen of all Committees, General Council Division Representatives only.

ENGINEERING SCHOOL LIBRARIES: I. A. Tumbleson, *Chairman,* Newark College of Engineering, Newark, New Jersey; R. E. Betts, Marguerite Chamberlain, D. M. Crosland, Madeleine Gibson, A. R. Krull, E. C. McClintock, J. H. Moriarty, Mary F. Pinches, Jeanette Poor, Samuel Sass.

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EVALUATION REPORT FOLLOW-UP (*ad hoc*): B. R. Teare, Jr., *Chairman,* Carnegie Institute of Technology, Pittsburgh, Pa.; G. G. Brown, C. S. Crouse, T. H. Evans, L. E. Grinter, H. L. Hazen, F. C. Lindvall, J. H. Rushton, E. Weber.

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GEORGE WESTINGHOUSE AWARD: R. S. Paffenbarger (1958), *Chairman,* The Ohio State University, Columbus, Ohio; G. S. Brown (1957), J. H. Rushton (1957), R. W. Van Houten (1958), G. N. Cox (1959), G. A. Marston (1959), W. K. Le Bold (1960), E. F. Obert (1960), Guy Kleis, *Ex officio.*

GRADUATE STUDY PROJECT (*ad hoc*): E. Weber, *Chairman,* Polytechnic Institute of Brooklyn, Brooklyn, New York; T. H. Chilton, N. A. Christensen, R. G. Folsom, N. A. Hall, H. L. Hazen, F. C. Lindvall.

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JUDGING OF THE YET PAPER CONTEST: Peter Balise, *Chairman,* University of Washington, Seattle, Washington; Margaret D. Blickle, W. H. Crater.

LAMME AWARD: C. L. Eckel, *Chairman* (1958), University of Colorado, Boulder, Colorado; L. H. Johnson (1957), R. C. Jordan (1957), J. P. Spielman (1957), W. P. Kimball (1958), N. F. Rode (1958), E. D. Howe (1959), J. H. Sams (1959), R. E. Fadum (1960), J. C. McKeon (1960), J. T. Retalliata (1960).

NATIONAL LEGISLATION: H. K. Work, *Chairman*, New York University, New York, New York; M. M. Boring, W. T. Cavanaugh, H. A. Meyeroff, P. H. Robbins.

NOMINATING: L. E. Grinter, *Chairman*, University of Florida, Gainesville, Florida; M. M. Boring, N. H. Barnard, L. V. Bewley, G. F. Branigan, R. S. Burington, E. T. Donovan, N. W. Dougherty, Harold Flinsch, J. W. Howe, H. K. Justice, K. A. Kobe, D. J. Peery, C. E. Schaffner, R. J. Seeger, W. I. Short, D. G. Stillman, R. W. Van Houten, E. L. Grant, J. G. Wohlford, J. H. Pitman.

PLANNING: S. C. Hollister, *Chairman*, Cornell University, Ithaca, New York; A. B. Bronwell, L. E. Grinter, B. R. Teare, Jr., E. A. Walker.

PUBLICATIONS: W. L. Collins, *Chairman*, University of Illinois, Urbana, Illinois; M. M. Boring, Renato Contini, G. W. Farnham, Paul Fatout, ex-officio, E. C. McClintock, R. A. Morgen, M. E. Van Valkenburg.

PUBLIC RELATIONS: J. I. Mattill, *Chairman*, Massachusetts Institute of Technology, Cambridge, Mass.; J. H. Bolton, E. C. McClintock, Jr., A. J. McNair, G. C. Pearl, R. W. Schmelzer, A. F. Thompson.

SECTIONS AND BRANCHES: F. C. Lindvall, *Chairman*, California Institute of Technology, Pasadena, California; Chairmen of all Sections, Chairmen of all Branches, General Council Section Representatives only.

SOCIETY FUNCTIONS: B. R. Teare, Jr., *Chairman*, Carnegie Institute of Technology, Pittsburgh, Pennsylvania; H. H. Armsby, H. W. Barlow, A. B. Bronwell, R. M. Green, S. C. Hollister, K. B. McEachron, Jr., D. H. Pletta, E. A. Walker.

STYLE BOOK (*ad hoc*): G. J. Christensen, *Chairman*, Lehigh University, Bethlehem, Pa.; A. A. Hobgood, W. C. Laity, E. C. McClintock, Jr., B. M. Nead, Fred Senseman, Max Linn.

SURVEY OF TEACHING OF ENGLISH IN COLLEGES OF ENGINEERING (*ad hoc*): C. A. Brown, *Chairman*, General Motors Institute, Flint, Michigan; M. M. Boring, G. G. Brown, G. B. Carson, G. J. Christensen, H. O. Croft, Thomas Farrell, Jr., Paul Fatout, C. B. Hill, Jr., J. C. McKeon, P. E. Mohn, J. H. Pitman, D. G. Stillman, R. L. Sweigert, R. W. Van Houten, J. L. Vaughan, W. R. Woolrich, E. L. Yates.

YET SUMMER INSTITUTE (*ad hoc*): W. T. Alexander, *Chairman*, Northeastern University, Boston, Massachusetts; J. L. Artley, N. A. Christensen, R. A. Emerson, H. A. Foecke, A. R. Hellwarth, E. K. Kraybill.

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Secretary: R. A. Means, Oklahoma A. & M. College, Stillwater, Okla.

Representative: L. A. Richardson, Pennsylvania State University, University Park, Pa.

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Secretary: M. H. Chetrick, University of Louisville, Louisville, Kentucky
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EJC THIRD GENERAL ASSEMBLY

January 17-18, 1957, Statler Hotel, New York City

The following preliminary program is subject to modification:

Thursday—January 17

8:00–10:00 a.m.	Registration
10:00	General Assembly and Welcome
10:10	Panel—Problem of Engineers in Public Service
11:00	Discussion Period
12:30	Luncheon—Speaker—J. B. Rae, M.I.T.
2:00	Panel—Analysis of Salary Practices
4:00	Discussion Period
6:00	Reception
7:00	Dinner—EJC President's Report—Speaker, H. T. Heald, Ford Foundation

Friday—January 18

9:00 a.m.	Registration
10:00	Panel—Engineering and International Relations
11:15	Discussion Period
12:30 p.m.	Luncheon—Speaker—E. Black, President, International Bank for Reconstruction and Development
2:00	First Meeting of EJC 1957 Board of Directors, open meeting for Associate and Affiliate member societies

GRAPHIC SCIENCE

Analysis—Synthesis—Communication

Sponsored by the Engineering Drawing Division
Editor: Albert Jorgensen, University of Pennsylvania
Editor Elect: J. N. Arnold, Purdue University

"FIRST CLASS" THOUGHTS ON FRESHMEN

JOHN M. RUSS

Head, Department of Engineering Drawing
The State University of Iowa
Iowa City

The thrill of anticipation which comes to me as I walk into a classroom to meet a new class of freshmen for the first time is one which grows year after year, and one which I hope will never diminish. It is doubtful whether the students ever realize what is going on in the mind behind the friendly face which I try to present as I look them over contemplatively while attempting to put them at ease. A variety of questions are arising and competing for attention behind my mask.

One question has to do with a very human search for friendships. Many of my closest friends were first met at the moment we are now considering. Most of them have graduated and are successful in their profession; they are family men, towers of strength and influence in their civic and industrial communities. They are scattered all over the world, but find time to write and to keep in touch. So, this is one question I am silently asking as I meet them eye to eye, "Will you be among my future friends?"

Every man who has ever attended one of my classes has heard me imply, or quote from a distinguished colleague, "Look well to your right and to your left. When you graduate, one of these men will not be with you." Why will some fail to accomplish what they are setting out to do? How many will leave before graduating? That this happens is one of life's tragedies. It is frequently a matter of luck, finances, conditions at home, or worse still, too much attention to frivolities or too little application of intellectual stamina. The actual difference between the man who leaves during or after his first semester and the man who graduates with honors is very small.

How many will blow up under pressure during an exam, in spite of having carefully learned the material? I use examinations copiously. To inquire? Yes, but more fundamentally as a teaching device. I capitalize heavily on the psychology of that fearful word "Exam." But why should it be *fearful*? Why, rather, should it not be a finger that wipes away the film of dust from the polished surface of knowledge? Why not think of examinations as being slyly strewn stumbling blocks that will eventually pave highways to greater knowledge? In

industry every task will be an exam. You don't "flunk" on the job. You make good or you are fired.

How many will plunge with ardor into extra-curricular activities? Who will take advantage of the fact that this is a university campus, with its lectures, music, and drama? How many realize that your classmates are future leaders of your community, state, and nation? Will you seek, justify, and hold friendships with the now embryonic key men of a generation? These are the factors, these are the catalysts, which, when blended with technical training, will yield the priceless future of a full and balanced life.

How many will be able to supply or find the ingredient, which when combined with opportunity, is inherently necessary to human development? The university is offering you the opportunity. You must furnish the incentive. Do you know that Ulysses Grant was unsuccessful as late as four years before the threat of impending catastrophe forced him to display the previously hidden qualities that placed him in charge of the Union Armies? Do you know that Abraham Lincoln was a happy-go-lucky country lawyer until six years before a national crisis placed him in the President's chair? Four years later he had become a leader in world thought.

How many of you have similar latent talent? How many will ever know it? What can I do to kindle it? What can I do to help you discover it? What can I do to keep it alive and available for the years that lie ahead? These are the thoughts that are surging for response, behind the smile and the challenge with which I meet you on the occasion of our first class.

TEACHING POSITIONS AVAILABLE

Associate Professor or Professor needed in Mechanical Engineering positions, all branches, combining teaching and research on a twelve month basis. Ph.D. preferred, can start during the school year. Write to the M. E. Department, Alabama Polytechnic Institute, Auburn.

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35 New Members
50 Previously Added

85 New Members This Year

ARTHUR R. CARR

Arthur R. Carr, Dean of the College of Engineering at Wayne State University, died suddenly June 12, 1956, at the age of sixty-three years. A member of ASEE since 1927, Dean Carr has headed the College since its organization in 1933.

ANNOUNCEMENT OF AWARDS

(See page 189 for Nomination Form)

LAMME AWARD

The Lamme Award consists of a gold medal and bronze replica bestowed annually upon a distinguished engineering educator for excellence in teaching and contributions to the art of teaching; contributions to research and technical literature; achievements which contribute to the advancement of the profession; and engineering college administration. The Lamme trust fund was established in memory of Benjamin Garver Lamme in 1928.

Qualifications

The following qualifications of nominees for the Lamme Award will be considered by the Lamme Award Committee in selecting the recipient:

1. Excellence in teaching and ability to inspire students to high levels of accomplishment.
2. Improvement of engineering education through contributions of books, technical articles, or research which have a lasting influence on engineering education.
3. Administration of engineering schools which has led to definite and recognized improvements in the arts of engineering education.
4. Participation in the work of engineering and educational societies which has led to improvement of engineering education.
5. Achievements outside the field of teaching, such as development in industry, consulting work, inventions, government service, etc. Such achievements will be considered secondary in importance in selecting the recipient.

Nominations

Nominations for the Lamme Award can be made by any member of the Society.

Nominations should emphasize the contributions of the candidate to the improvement of engineering education. Concise statements of achievements are of more value than numerous recommendations of former students. Information from "Who's Who" is helpful but should be supplemented by information as to specific contributions to the improvement of engineering education.

In preparing the biography of a nominee, the following outline is suggested:

1. Name, age, title of present position.
2. Academic preparation for teaching, including schools attended, year graduated, degrees, post-graduate work, honorary degrees, etc.
3. Distinguished accomplishments as a teacher.
4. Advancement of the art of engineering education including books, articles, contributions to research, etc.
5. Administrative work in engineering schools.
6. Membership and participation in engineering and educational societies.
7. Engineering practice—employment in industry, consulting work, inventions, etc.
8. Other achievements.

Nomination forms and a convenient form for summarizing information may be obtained from the Committee Chairman or from the Secretary of the Society, W. Leighton Collins, University of Illinois, Urbana, Illinois.

Nominations should be submitted by letter to the Chairman of the Lamme Award Committee, Dean C. L. Eckel, College of Engineering, University of Colorado, Boulder, Colorado, on or before March 1, 1957.

ECRC RESEARCH AWARDS OPEN FOR NOMINATIONS

To encourage excellence in research by engineering college staff members, the Engineering College Research Council announces competition for two awards in 1956–1957. One, the Vincent Bendix Gold Medal, signalizes the achievements of mature engineers and scientists. The quality of nominees sought is exemplified by the 1956 and initial recipient, Dr. C. C. Furnas, former Director of the Cornell Aeronautical Laboratory and Chancellor of the University of Buffalo, a well-known author, now Assistant Secretary of Defense for Research and Development. This award is given with the assistance of the Bendix Aviation Corporation of Detroit.

The second, to be offered for the first time in June, 1957, honors Curtis W. McGraw and consists of a certificate and one thousand dollars. It is intended to encourage younger research workers, under forty years of age, in pursuing their careers, carrying further the promising investigations of which the preliminary fruits have gained the respect and admiration of fellow and senior workers in the field. This award has been made possible through the support of the McGraw-Hill Book Company of New York City.

Both awards are presented by the ASEE at its Annual Meeting in June. Nominations may be made by colleagues, research superiors, or by others familiar with the candidate and his work. Appropriate forms, giving detailed criteria and regulations, have been prepared. They will be distributed to and available from institutional representatives of ECRC, and will be published in an early issue of the JOURNAL. Additional copies can be obtained by writing to the selection chairmen, as indicated below, or to ASEE headquarters.

The selection committees will appreciate suggestions of suitable candidates, and hope to make the nomination procedures as simple as possible. Information needed will in general include a short (300 word) citation of accomplishments and reasons for meriting the award, giving specific achievements in and contributions to college research, including publications. This should be accompanied by a biographical sketch emphasizing research positions held, and identification of present affiliations. (Not more than six to ten supporting letters may be included, if considered necessary.) March 1, 1957, is the final date for submitting nominations, which should be sent to the Chairman of the appropriate award committee.

Vincent Bendix Award

Sponsored by the ECRC, this medal is presented in recognition of an outstanding record to research in engineering and the engineering sciences carried on by American colleges and universities. The recipient is selected annually on the basis of his achievements in and contributions to original research, research administration, leadership influencing the productive research of others, and the effective application of research results to the advancement of engineering education. There are no limitations on eligibility. Nominations may be sent to, or information requested from, Pro-

fessor Ross J. Martin, Bendix Award Committee Chairman, College of Engineering, University of Illinois, Urbana, or ASEE Secretary W. Leighton Collins.

Curtis W. McGraw Research Award

Primarily intended to recognize the outstanding *young* member of an engineering college research staff in the United States, the Curtis W. McGraw prize is limited to nominees who will be under 40 years of age on June 30, 1957. For this award, quality rather than quantity of research production is desired; indications of excellence are sought through acceptance of results by fellow-workers, by the reputation of the nominee and the significance of his efforts to other scientists and engineers in his field, and by the promises which his present achievements offer for the future. A Curtis McGraw recipient, projected ahead to the height of his career, might well be considered as the prototype of a Bendix Award winner. Nominations should be submitted to Dean James R. Cudworth, Curtis McGraw Research Award Chairman, College of Engineering, University of Alabama, Tuscaloosa. Further information can be obtained from him or from Secretary Collins.

GEORGE WESTINGHOUSE AWARD (See page 191 for Nomination Form)

The George Westinghouse Award is made under the following general conditions:

1. *Purpose.* To recognize and encourage outstanding contributions to the teaching of students of engineering.

2. *The Award.* A sum of $1,000 and an appropriate engraved certificate are to be given at the annual dinner of the Society in June, to a recipient selected by the American Society for Engineering Education. This award is made possible by the Westinghouse Educational Foundation.

3. *Fields.* Candidates may be teachers of any division of subject matter ordinarily taken by engineering students, including, besides the recognized divisions and subjects of engineering, such subjects as English, mathematics, physics, and chemistry.

4. *Requirements.* In order to receive the award, a person must have made a clearly discernible contribution to the art and science of teaching. He shall have established achievement in several of the following ways:

(a) Success as a teacher must be established both as to competence in subject matter and ability to inspire students to high achievement as demonstrated by the careers of former students.

(b) Improvement of the tools of, and conditions for, teaching. Evidence of such achievement may consist of subject matter (textbooks, etc.); courses or curricula; diagrams and models; laboratory or other teaching equipment; and other similar activities.

(c) Improvement of teaching through various activities, including the development of teachers in a department or in other schools, testing or guidance programs, promotion of co-operation with other types of educational institutions or with industry,

development of testing and guidance programs, and the co-ordination of fields of subject matter.

(d) Evidence of creative ability, scholarly contributions to literature, significant honors, etc.

The award has been established to encourage *younger men who show by their past record evidence of continuing activity as superior teachers and who are in the process of carrying on projects for the improvement of teaching in engineering.* To them the award may serve not only as a reward but as an incentive toward further work which the funds might make possible.

To accomplish this intent, it is deemed essential to limit the award to those who have not reached the age of 45 before the July 1st of the year of presentation of the award.

5. *Committee on Awards.* The award will be made upon the recommendation of a Committee on Award, the members of which are appointed by the President of the American Society for Engineering Education. One of the proper functions of this Committee is to develop criteria for judging outstanding teaching.

6. *Nominations.* Nominations may be made by any person, organization or group other than members of the Award Committee. Nominations will be received up to March 1 of the year in which the award is to be presented. Nominations are to be made on forms available from W. Leighton Collins, Secretary of the Society, University of Illinois, Urbana, Ill., and from members of the Committee. Nominations should be sent to the Chairman of the Committee and must be accompanied by documentary evidence supporting major statements and claims.

THE JAMES H. McGRAW AWARD IN TECHNICAL INSTITUTE EDUCATION

The James H. McGraw Award in Technical Institute Education is made to recognize outstanding service in technical institute education. This growing educational movement is a part of the broad tertiary level of instruction that prepares engineering technicians for the present-day engineering team. Encompassed within the expanding field of engineering, technical institute education emphasizes the use of rational processes and the application of science and mathematics in programs of post-high school training. Instruction in technical institute education lies between highly theoretical professional engineering studies and artisanship training. It integrates the "why" with the "how."

The Award is made under the following general conditions:

1. Fields. Candidates may be teachers, authors, or administrators who are, or have been, affiliated with an institution which offers or sponsors training of the technical institute type.

2. Requirements. In order to receive the award a person must have made a clearly discernible contribution to technical institute education. He shall have established achievement in one or more of the following activities:

(a) Teaching. (Evidence of outstanding subject-matter competence, student guidance, course development, etc.)

(b) Publications. (Textbooks, articles, reports, bulletins, tests, etc., in the field of technical institute education.)

(c) Administration. (Outstanding contributions to curriculum development, cooperation with industry, student selection and placement, buildings and facilities, etc.)

(d) Other activities. (Participation in technical institute studies and surveys, leadership in appropriate local and national technical institute groups, etc.)

3. The Award. An annual award of the sum of $500 and an appropriately engraved certificate is to be given at the annual dinner of the Technical Institute Division of the American Society for Engineering Education in June. This award is made possible by the McGraw-Hill Book Company in memory of James H. McGraw.

4. Nominations. Nominations may be made by any person, organization, or group other than members of the Award Committee, or employees of the McGraw-Hill Book or Publishing Companies. Members of the committee, in any capacity, are not eligible to receive the award. No award shall be made if in any given year, in the opinion of the committee, the nominees do not qualify for the award. Nominations will be received up to March 1, 1957. The committee shall disregard all nominations and material concerning nominees received after the closing date of March 1. Nomination forms may be secured by writing to Mr. K. O. Werwath, Chairman of the Technical Institute Division, ASEE, Milwaukee School of Engineering, Milwaukee, Wisconsin, or to Mr. L. V. Johnson, Chairman of the James H. McGraw Award Committee, Southern Technical Institute, Chamblee, Georgia. Nominations are to be submitted to the chairman of the committee and must be accompanied by documentary evidence supporting all statements and claims.

CHEMICAL ENGINEERING FACULTIES 1956-1957

The Chemical Engineering Projects Committee of the American Institute of Chemical Engineers has published its annual booklet, "Chemical Engineering Faculties, 1956–1957." Citing the schools and departments offering chemical engineering in the United States and Canada, the brochure contains information about accreditation, degrees granted, the names and rank of the faculty members, and placement officers. This 49-page list can be obtained without charge from the Executive Secretary, American Institute of Chemical Engineers, 25 West 45th Street, New York 36, N. Y.

Members have requested that the application blank be reproduced more often, so that it could be available for potential new members. Accordingly, it is printed below.

APPLICATION FOR MEMBERSHIP

Date .....

I desire to become a member of the American Society for Engineering Education and hereby agree to conform to the requirements of membership, if elected, and submit the following statement of qualifications:

Name .....
Print last name First Middle

Mailing address .....

City and State .....

Full title of
professional position .....
Title Department

Institution ..... Date of Birth .....

Degrees and names of institutions granting .....

Sponsors .....

.....

Desired Division Affiliation .....

To be signed by two sponsors, members of ASEE, and returned to
W. L. Collins, Secretary, ASEE, University of Illinois,
Urbana, Ill.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Nomination Form

LAMME AWARD
IN
ENGINEERING EDUCATION
1957

Date .....

Full name of nominee .....

Address .....

Date and place of birth .....

Present position (s) .....

Earned degrees, institution, ...

date and field .....

Honorary degrees, institution .....

Basis for nomination

Submit on separate sheets, as much information as you can regarding the achievements and contributions of the nominee. It is helpful to have more information than is usually given in a who's who biography, in order to evaluate the effectiveness of the candidate's contributions.

1. Record as a teacher. (Evidence of superior teaching and guidance of students as demonstrated by records of former students, indications of unusual subject matter competence, etc.)

2. Improvements of the tools of teaching and other activities contributing to the improvement of teaching.

3. Evidence of high intellectual capacity. (Brilliance of mind as manifested by contributions to literature, research, degrees and honors received, etc.) A few letters of recommendation from colleagues and former students are helpful. They should be brief.

4. Administrative achievements in his own institution and contributions to the work of ASEE and to other engineering societies.

Nomination prepared and presented by .....

Institution .....

Return this blank before February 1, 1957, to Dean C. L. Eckel, College of Engineering, University of Colorado, Boulder, Colorado.

THE LAMME AWARD

The Committee on Lamme Award is always anxious to get nominations for the Award from the membership of the Society. Any member may place a name in nomination; the selection will be made by the Committee by letter ballot.

The Lamme Award consists of a gold medal and bronze replica bestowed annually upon a distinguished engineering educator for excellence in teaching and contributions to the art of teaching; contributions to research and technical literature; achievements which contribute to the advancement of the profession; and engineering administration. The Lamme Trust Fund was established in memory of Benjamin Garver Lamme in 1928. For a brochure describing the Award and a nomination form, please write to the Secretary of the Society, W. Leighton Collins, University of Illinois, Urbana, Illinois, or to members of the committee.

Nominations should be sent to the Chairman of the Committee, Dean C. L. Eckel, College of Engineering, University of Colorado, Boulder, Colorado, by February 1, 1957.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Sponsored by the Westinghouse Educational Foundation

Nomination Form
GEORGE WESTINGHOUSE AWARD
IN
ENGINEERING EDUCATION
1957

Date .....

Full name of nominee .....

Address .....

Date and place of birth .....

Present position (s) .....

Earned degrees, institution, ...

date and field .....

Honorary degrees, institution .....

Basis for nomination

Submit on separate sheets, the statements and evidence testifying to the achievements and contributions of the nominee. Each claim must be supported by attached documentary evidence and/or by reference to published or other material which is not feasible to include. The supporting evidence must be arranged in accordance with the following outline. Remember that most of the committee will not be personally acquainted with the nominee.

1. Record as a teacher. (Evidence of superior teaching, stimulation, and guidance of students.) This qualification is not met by mere skill in classroom exposition or unusual subject matter competence. It involves demonstrated achievement in the development of young men to the place where they accept the challenges and responsibilities of the engineering profession. Present as complete a record of his teaching career as possible. (Letters of recommendation from colleagues and former students are important, but should be brief and limited to not over a dozen.)

2. Improvements of the tools of teaching. (Textbooks and student notes, descriptions of special courses or curricula, diagrams and models, new laboratory and teaching equipment, etc.) Include reference list of this material.

3. Other activities contributing to the improvement of teaching. (Material relating to the development of teachers in the nominee's department or teachers in general, the development of testing and guidance programs for students, the promotion of cooperation with other types of educational units or with industry, coordination of fields of subject matter, etc.)

4. Evidence of high intellectual capacity. (Brilliance of mind as manifested by creative work, contributions to literature, degrees and honors received, etc.)

Nomination prepared and presented by .....

.....

Return this blank before March 1, 1957, to Professor R. S. Paffenbarger, Chairman, George Westinghouse Award Committee, Department of Engineering Drawing, The Ohio State University, Columbus 10, Ohio.